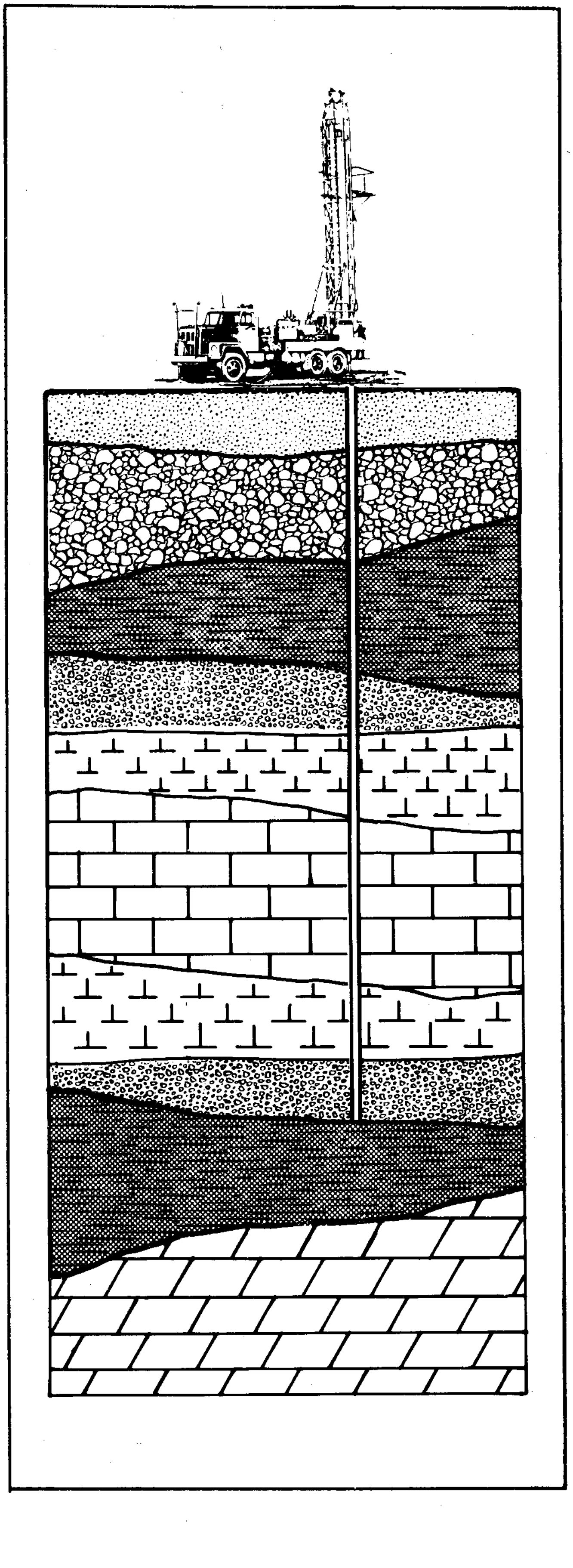


BOTETOURT COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS

by

N. K. Breeding, Jr.
J. W. Dawson

WEST CENTRAL REGIONAL OFFICE

COMMONWEALTH OF VIRGINIA

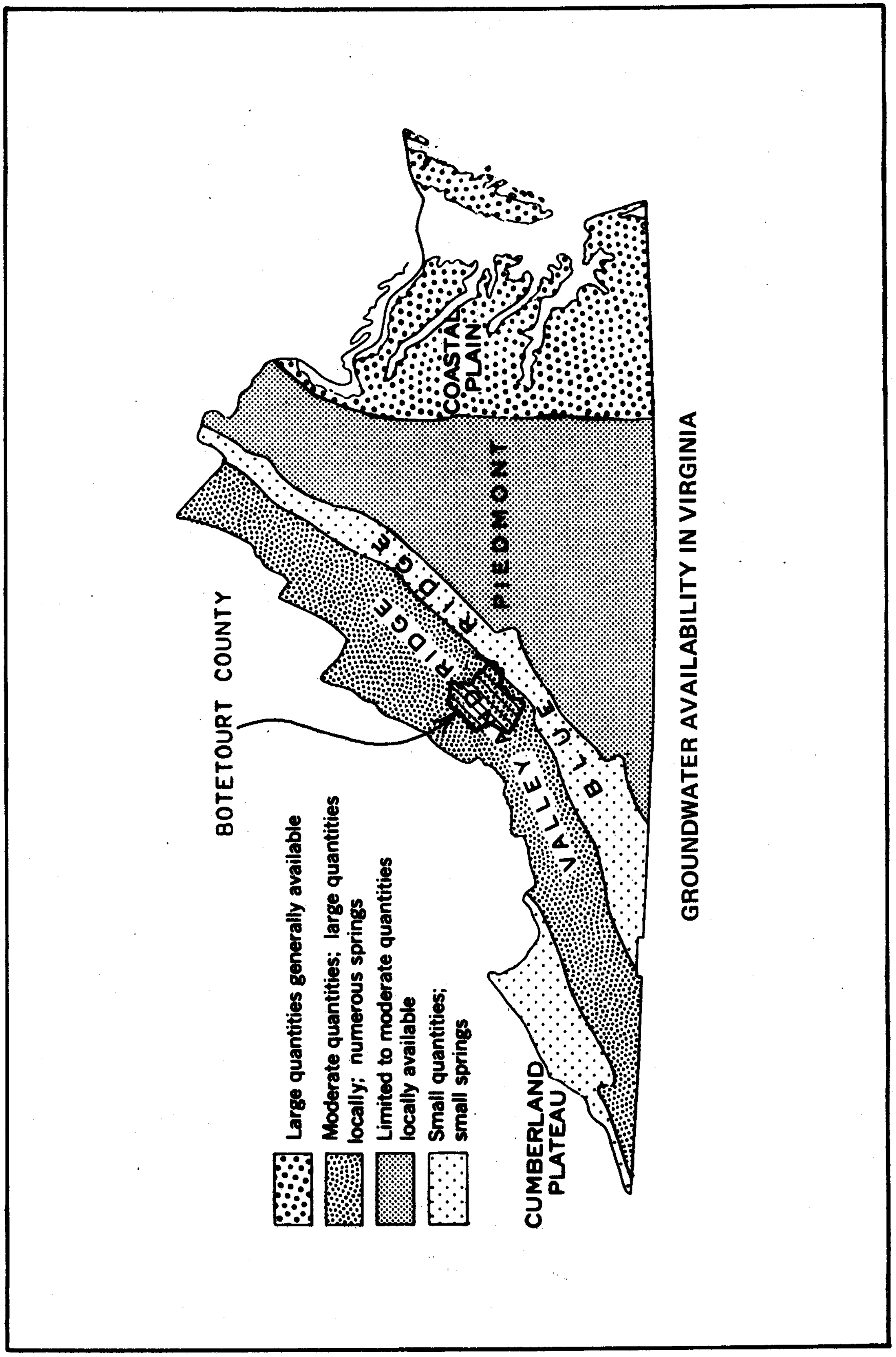
STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 304

September 1976

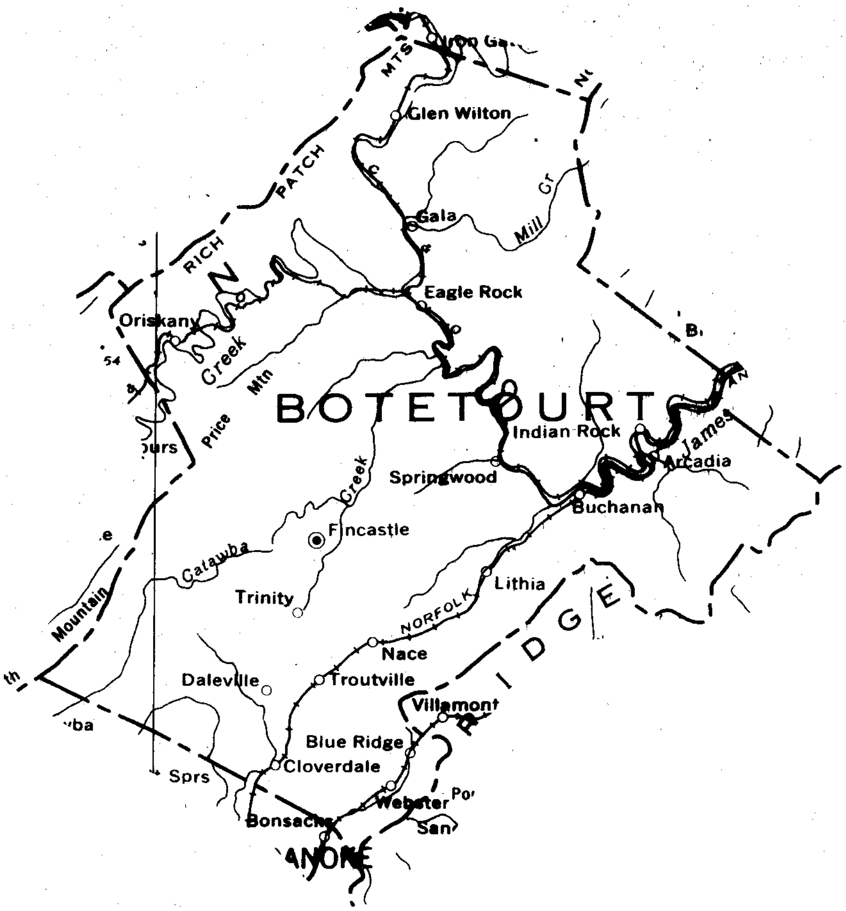


Source: Virginia State Water Control Board – BWCM

Frontispiece

BOTETOURT COUNTY GROUNDWATER

PRESENT CONDITIONS AND PROSPECTS



By

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West Central Regional Office

Virginia State Water Control Board
Bureau of Water Control Management
Richmond, Virginia

Planning Bulletin No. 304
September, 1976

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ACKNOWLEDGMENTS

Appreciation is expressed to the citizens of Botetourt County, Fincastle, Troutville, Daleville, Buchanan, and Eagle Rock who furnished information on their wells and who permitted water quality samples to be taken. The officials of the aforementioned municipalities were most cooperative in supplying information on public water supply wells, as was the State Department of Health in furnishing copies of chemical analyses of these wells. Several water well contractors who operate in the County deserve thanks for supplying valuable information on construction characteristics and well data. Thanks is given to Dr. James O. Waller for providing information and assistance in regard to aquifer systems. A special appreciation is extended to the Division of Mineral Resources and the Soil Conservation Service for information in regard to geology and soils.

FOREWORD

This report is part of a series intended to cover the entire State and to provide private citizens, groundwater users, developers, investors, well drilling contractors, consultants and professionals, and goverment officials with as complete a picture as possible of the groundwater situation, including prospects, as it exists in each of the counties of Virginia.

On the basis of this report, prospective groundwater users and anyone else interested in the development and protection of that invaluable resource that is groundwater can make up their minds and call a consulting hydrogeologist to handle their specific groundwater problem, while the State Water Control Board remains at the public's service for general information and governmental action.

BOTETOURT COUNTY GROUNDWATER REPORT

Present Conditions and Prospects

ABSTRACT

Botetourt County is situated in a mountainous area that has undergone numerous geologic processes which have resulted in complex geologic conditions. Intensely folded and faulted sedimentary rocks comprised mainly of shale, sandstone and limestone underlie the majority of the County with minor amounts of igneous and metamorphic rocks along its eastern boundary. In addition to valuable water-bearing alluvium of stream valleys, four aquifer systems have been identified which provide about 1.5 million gallons per day of groundwater for public, private and and industrial use. These aquifer systems have the potential to provide approximately ten times this amount from presently developed wells.

The Pre-Cambrian-Cambrian Aquifer System is present only in the extreme eastern portion of the County. No current information is available on the quality or availability of groundwater in this aquifer system, however, in adjoining Roanoke County, it has fair to good water-bearing characteristics, with local areas of high yields.

The Cambrian-Ordovician Aquifer System occurs in the major valley areas east of the Pulaski-Staunton Fault Zone. This aquifer has good to excellent water-bearing characteristics with generally excellent water quality, although hardness problems may be encountered in isolated areas. About 75 percent of the County's water needs are met by this aquifer system, with excellent potential for future development.

The Mississippian-Devonian-Silurian Aquifer System underlies the western and northern portions of the County. Wells in this system have poor to fair yields with generally poor to fair water quality, with

excessive iron and sulphur common. Approximately 16 percent of the County's needs are served by this aquifer and potential for future development is considered poor.

The Upper Silurian-Lower Devonian Aquifer System occurs within the boundaries of the MDS-AS, but is very different hydrologically. Although limited in areal extent, this system provides good to excellent yields for domestic purposes with water quality generally good. Currently, about 1 percent of the County's needs are served by this aquifer and potential development is good for domestic or small industrial purposes.

Groundwater is probably the most abundant natural resource in Botetourt County and one that requires adequate conservation and protection. Although the County is presently rural in nature, future development must not contravene the generally good quality groundwater of the County. Prevention is the key to maintaining groundwater quality because once contaminated it is difficult, if not impossible, to restore it, due to limitations of technology and the cost involved.

CHAPTER I

INTRODUCTION

Background

Botetourt County, encompassing approximately 548 square miles, is located in west central Virginia (Plate 1). It is rural in nature, three-fourths covered by forest land, with George Washington and Jefferson National Forests extending into the County. The main economic activity is well distributed among agriculture, manufacturing and minerals production.

There are six major towns within the County: Buchanan, Troutville, Fincastle, Daleville, Eagle Rock and a portion of Iron Gate. The largest, Buchanan, has a population of about 1,815. According to the Division of State Planning and Community Affairs, the total population of the County was about 19,000 in 1972. Growth in the County has been concentrated in the southern portion due to it's proximity to the Roanoke Metropolitan Area. For the years 1985 and 2000, the population is projected to be approximately 21,400 and 23,000 respectively.

All of the water needs are presently being served by groundwater. Current information indicates that about 1.5 MGD of groundwater is used in the County, while information on completed wells indicates that approximately 7 MGD of groundwater could be obtained from present wells, if so desired. In view of this, the potential for groundwater has just been tapped, and there is room for additional groundwater development.

To appreciate groundwater as a resource, one must understand the relationships between physical setting (climate, precipitation, soils, vegetation), geology (formations, faults, fractures, aquifer systems), present water quality problems, and the potential, development and management of this resource. In the following chapters, these subjects are discussed in a generalized fashion to give the reader an understanding of the intricacies affecting groundwater quality and availability.

Groundwater meets 100 percent of the present water supply requirements in the County and if appropriate development and management of this resource is achieved it can supply the needs of the future.

Purpose and Scope

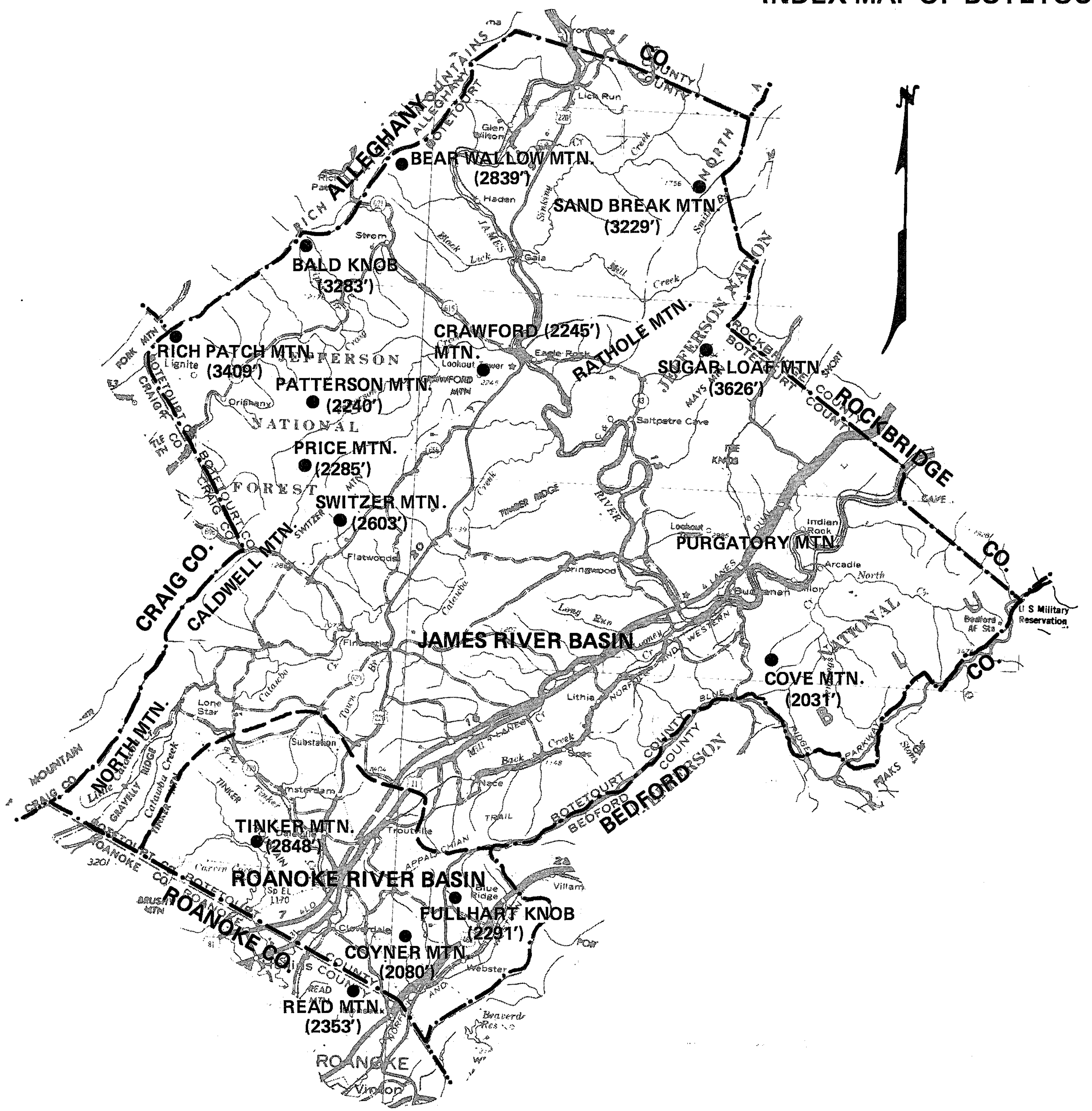
The purpose of this report is to consolidate available information on groundwater in Botetourt County and to provide individuals, industries and municipalities with a concise picture of the groundwater resources in the County and how these resources may be developed to supply the present and future needs of the County. Although directed towards the layman, this report should provide basic information useful to professionally oriented readers.

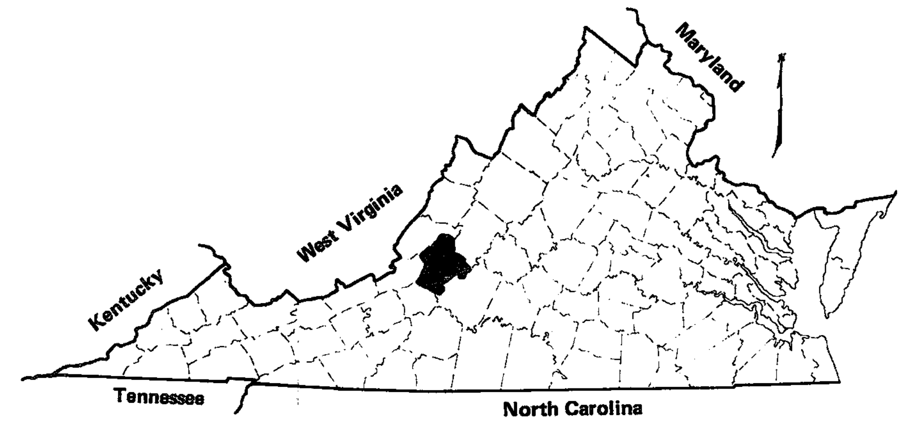
Methods of Investigation

Most of the general background and geologic information appearing in this report is a summary of previous work. Some of the information on water well construction and groundwater quality has been obtained from other State Agencies, although the majority of it has been collected by the State Water Control Board.

Much of the previously unpublished information on individual well construction data and quality analyses has been collected as a result of the Groundwater Act of 1973. This Act requires that water well drilling contractors submit a Water Well Completion Report (Form GW-2) for all wells drilled, and that owners of industrial and public water supplies submit quarterly reports (Form GW-6, Groundwater Pumpage and Use) detailing groundwater withdrawal. In addition, the Board requires that drillers

INDEX MAP OF BOTETOURT COUNTY

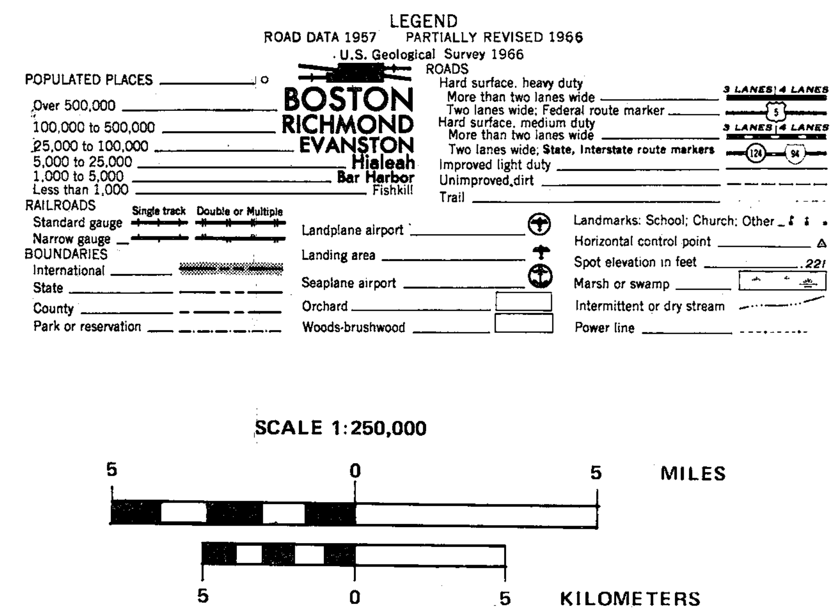




POPULATION:
1972 : 19,000
1985 : 21,400
2000 : 23,000

AREA:
County: 548 sq. miles
James River Basin - 479 sq. miles
Roanoke River Basin - 69 sq. miles

– – – – –River Basin Boundary



Source: Virginia State Water Control Board — WCRO

PLATE NO. 1

submit drill cutting samples collected at ten-foot intervals on all public and industrial supply water wells and those wells which are drilled to unusual depths or are located in areas deemed deficient in geologic information.

A concentrated effort has been made over the past year to gather information relating to groundwater quality trends in Botetourt County. In addition to specific sampling areas, groundwater quality information is obtained from regular monthly sampling runs throughout the Board's West Central Region. Domestic supplies are generally sampled although some small industrial and commercial supplies are checked occasionally.

Another source of quality information is the Pollution Response Program (PReP), maintained by the Board for the sole purpose of responding to citizen reports of water pollution of any type. This includes pollution of both groundwater and surface water by accidental or intentional spills of hazardous chemicals, oil, gasoline, refuse and industrial wastes.

All well information, well completion reports and records of groundwater quality analyses cited in this report are on permanent file at the Board's Headquarters Office in Richmond and in the West Central Regional Office in Roanoke. This data is computerized for storage and retrieval and was used to compile Appendix A and Appendix B.

Previous Investigations

Several geologic investigations have been made of the Roanoke area which includes part of Botetourt County. The earliest geological investigations were by Watson (1907), Harder (1908-1909), and by Stose, et.al. (1919) and were concerned about iron and manganese ore along the foot of the Blue Ridge Mountains. Later, Woodward (1932) and Butts (1933) presented the results of two geological investigations that encompass maps delineating various geological units. More specific and recent reports of the geology of the area have been conducted by Butts (1940), Andrews (1952), Dennison (1956), Edmundson (1955), Chen (1959), Hergenroder (1966), and Walker (1966). Recently, Spencer (1968) and McGuire (1970), completed detailed geologic mapping of eight quadrangles at a scale of 1:24,000.

Groundwater characteristics of the area were summarized by Latta (1956), and included a compilation of water well data. The most recent work, by Waller (uppublished Ph.D. dissertation and State Water Control Board report, 1976), is a comprehensive study of the water resources of the Upper Roanoke River Basin, emphasizing aquifers and groundwater in Roanoke County and portions of Botetourt, Floyd and Montgomery counties.

Water Well Numbering System

The State Water Control Board's Bureau of Water Control Management maintains water well information such as well size and depth, yield, and other pertinent data in a computerized system at the Board's Richmond Headquarters. Also, information on water quality and water level changes is computer maintained at Richmond by the Board's Bureau of Surveillance and Field Studies. Retrieval of this information for specific wells is possible by the water well numbering system.

This system comprises two numbers: the first one is a county identity number, (Botetourt County is 111), and the second number is a sequential listing of wells in the County. For example, well number 111-58 refers to a specific well in Botetourt County. At the time of this report over 135 wells are listed in the file for this county, although, it is estimated that the total number of wells in the county is substantially higher.

CHAPTER II

PHYSICAL SETTING

Physiography

Botetourt County lies within the Blue Ridge and the Valley and Ridge Physiographic Provinces. Locally, the physiographic units include the (1) Blue Ridge Mountains along the southeastern portions of the County; (2) North Caldwell, Rich Patch Mountains Complex of the Valley and Ridge Province in the northwestern area of the County; and (3) Roanoke Valley referred to locally as the Fincastle Valley which is broad and flat and comprises the central portion of the County.

The major topographic features of the County (Plate 1), exhibit approximately 2,866 feet of relief between the summit of Sugarloaf Mountain (3,626 feet), and the James River, where it leaves the County (760 feet). The central portion of the County is typified by gentle rolling hills with various agricultural activities. The southeastern portion of the County features forested mountains intersected by narrow, steep-sided ravines and valleys. The topography of the western and northwestern portion of the County is characterized by the long, narrow, parallel, northeast-trending valleys and mountain ridges of the Valley and Ridge Physiographic Province. The mountains in this part of the County are generally rugged and heavily forested with numerous small streams dissecting them.

Hydrology

The majority of the County (479 square miles), lies within the James River Basin, while approximately 69 square miles of the southern portion of the County lies within the Roanoke River Basin. Carvins Cove represents the only water supply impoundment in the County, which is owned by the City of Roanoke, while all water supply needs for Botetourt County are met by groundwater. Several stream flow gauging stations are maintained throughout Botetourt and adjacent counties. The data from these are published annually by the U.S. Geological Survey in "Water Resources Data for Virginia". The extremes of discharge values for the water year of 1974 are shown below along with the maximum recorded flow during the period of record (1925 to present):

TABLE 1

EXTREMES VALUES FOR DISCHARGE IN CUBIC FEET PER SECOND

Station	Period of Record Maximum	Maximum (1974)	Minimum (1974)
James River at Lick Run	66,600 ft. ^{3}/s 1936	54,200 ft.^{3}/s	289 ft.^{3}/s
Craig Creek at Paar, Va.	20,200 ft. ^{3}/s 1972	6,790 ft.^{3}/s	63 ft.^{3}/s
Catawba Creek Near Catawba	7,740 ft.^{3}/s 1972	1,820 ft.^{3}/s	5.5 ft.^{3}/s
James River at Buchanan	115,000 ft.^{3}/s 1913	73,400 ft.^{3}/s	489 ft.^{3}/s
Tinker Creek near Daleville	4,000 ft.^{3}/s 1972	3,580 ft.^{3}/s	2.8 ft.^{3}/s

Climate and Precipitation

A relatively mild climate characterizes Botetourt County, hot and humid in summer, cool and rainy in winter with some snow. The average annual temperature is about 55 degrees Fahrenheit; the hottest month being July with an average temperature of 75 degrees Fahrenheit and January being the coldest month with an average temperature of 36 degrees Fahrenheit. Precipitation during the warm months (April-September) averages about 23 inches, while the fall and winter months experience about

16 inches (some of it snow, but predominately rain), with an average yearly precipitation of about 40 inches.

Soils and Vegetation

In part, groundwater conditions are influenced by soils and vegetation, while the properties of soils partly depend on the underlying geology. In view of this, a generalized discussion of soil conditions is presented below. For example, a soil developed on sandstone will have a higher sand content than a soil developed on limestone. Eighteen major soil associations are recognized in Botetourt County; however, for simplicity they are consolidated in five major types of soils.

Blue Ridge Complex soils tend to generally be deep, well-drained and permeable on sloping to steep relief of the mountains. Due to their thickness and permeability, they act as a sponge, allowing water to continue, over long periods of time, to infiltrate underground and thus replenish the groundwater.

Limestone and Dolomite soils are mostly deep, moderately well-drained gently sloping, moderately permeable soils of the limestone valley. Due to the development of sinkholes, infiltration is directed into sinkholes with little passing through the soil cover.

Sandstone and Shale soils are mostly shallow, well-drained, permeable soils found on the steep slopes of the mountains. These soils permit rapid infiltration into the groundwater regime.

Colluvial Soils are mostly deep, well-drained, moderately permeable soils on gently sloping to moderately steep slopes. These soils occur along the lower portions of the Blue Ridge Mountains. They allow a slow continuous recharge to the groundwater.

Alluvial Sediment (Flood Plain and Terrace Deposits) soils are well to poorly-drained with moderate to poor permeability on gently sloping to nearly level stream terraces. They can store large volumes of water to replenish underlying aquifers.

Vegetation: Botetourt County has abundant vegetation as a result of the relatively mild climate and sufficient precipitation. Large stands of deciduous and evergreen trees cover the mountain slopes, with valley areas primarily having grass for grazing and agriculture crops present. This heavy vegetative cover inhibits surface run-off and subsequently permits larger amounts of water to percolate underground. However, if large areas are denuded of vegetative cover, whether trees or grass, higher surface run-off figures result, thus allowing less water to replenish the groundwater regime. In time these practices may result in decline in the water table.

CHAPTER III

HYDROGEOLOGY

Introduction

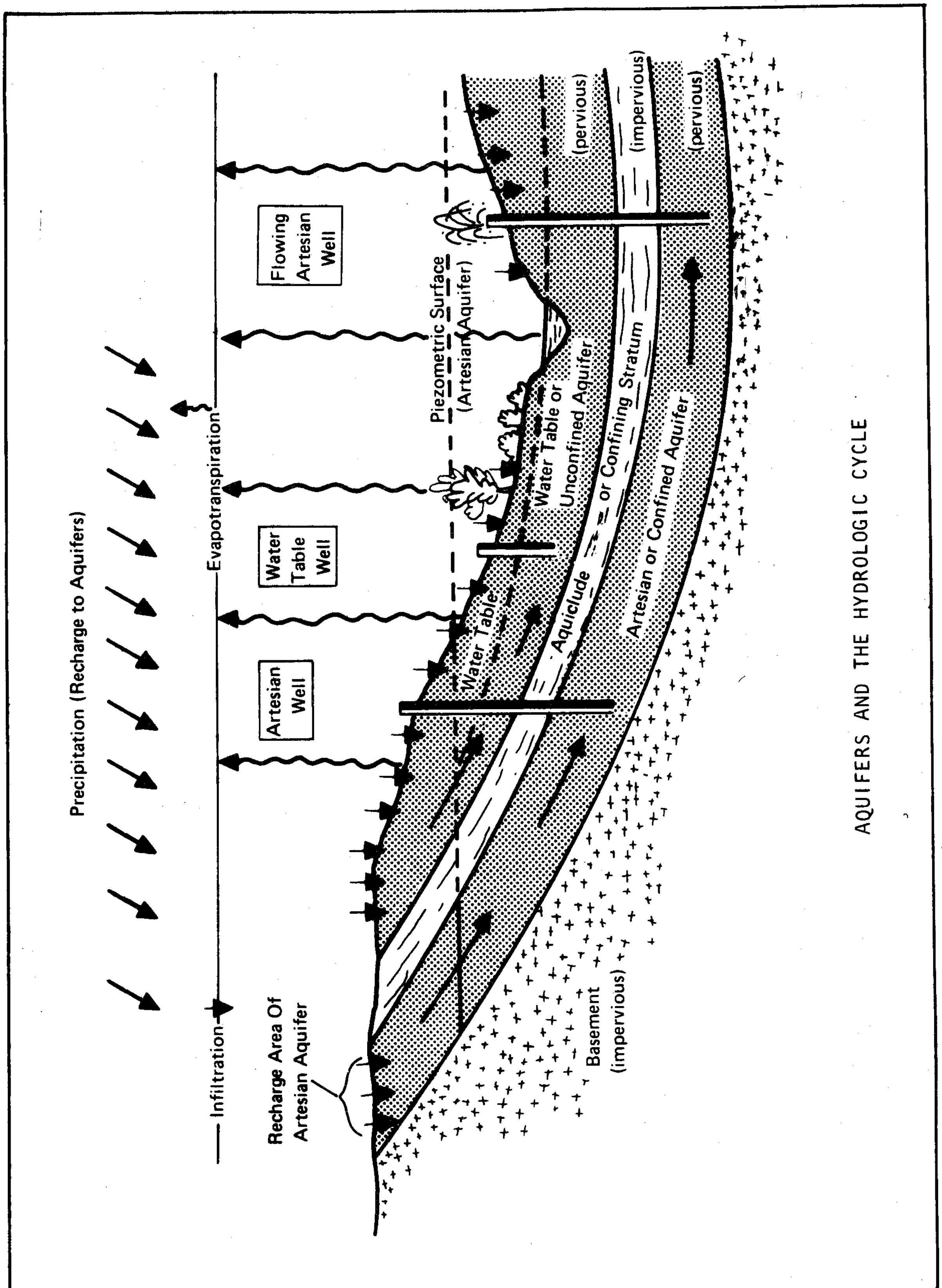
The occurrence, movement, availability and quality of groundwater is intimately related to the geology of a particular area; therefore, the knowledge of the geologic framework is a requisite to understanding the hydrogeology of any area. Many factors control groundwater conditions, the most important being the lithology (types of rocks) and the geologic structure (folds, faults). The ability of different types of rocks to store (porosity) and transmit (permeability) water varies greatly according to their nature and subsequent structural deformation which may either foster or impair groundwater conditions. Rocks which act as a reservoir and allow water to move are termed aquifers, while those which do not have this property are termed aquicludes. A generalized diagram of aquifers and the hydrologic cycle (the circulation of water on and above the land surface and underground), is shown on Plate 2. Groundwater is constantly moving over extensive distances from areas of recharge (infiltration) to areas of discharge (springs, wells, etc.), but movement is very slow compared with surface water velocities. Movement of groundwater is closely controlled by topography (generally from high to low elevation) and geology.

The three major rock types, (igneous, metamorphic and sedimentary), are present in Botetourt County. Igneous and metamorphic rocks have similar water-bearing properties and make up about 10 percent of the County. The porosity and permeability values are near zero in unweathered granites, gneisses and many other crystalline rocks, and these rocks generally are not considered good aquifers. However, once geologic processes alter the rocks over long periods of time, there is room for water to occur in fractures, faults, along contacts between the rock types, joints and other small openings. Fractures usually become smaller and fewer with depth while some of the metamorphic rocks such as phyllite, slate and schist may contain water along the cleavage planes.

Sedimentary rocks form about 90 percent of the rock underlying the County. Water occurs in voids, bedding planes, fractures and solution channels. Consolidated rocks such as limestone and dolomite have highly erratic water bearing properties. Porosity is frequently moderate or low, but where joints have been enlarged into solution channels by the disolving action of water, large volumes of water may be transmitted and stored. Unconsolidated sediments, such as sand and gravel are generally good aquifers, but less so when they have a high content of clay.

Geologic Setting

Botetourt County is principally located in the highly folded and faulted norther Appalachians, which exhibit a very complex geology. Folding and faulting are extensive in the Valley and Ridge portion of the County (Plate 3). The anticlines and synclines resulting from folding play a significant role with respect to groundwater; for example, water collected in valleys eroded into anticlines is channeled into the limbs and troughs of the adjoining syncline where it may be under appreciable artesian head (Plate 3). Faults are breaks in the earth's surface along which there has been displacement of rock masses relative to one another. In the County, faults vary from low-angle thrust faults to high-angle normal and reverse faults. In the Valley and Ridge portion of the County,

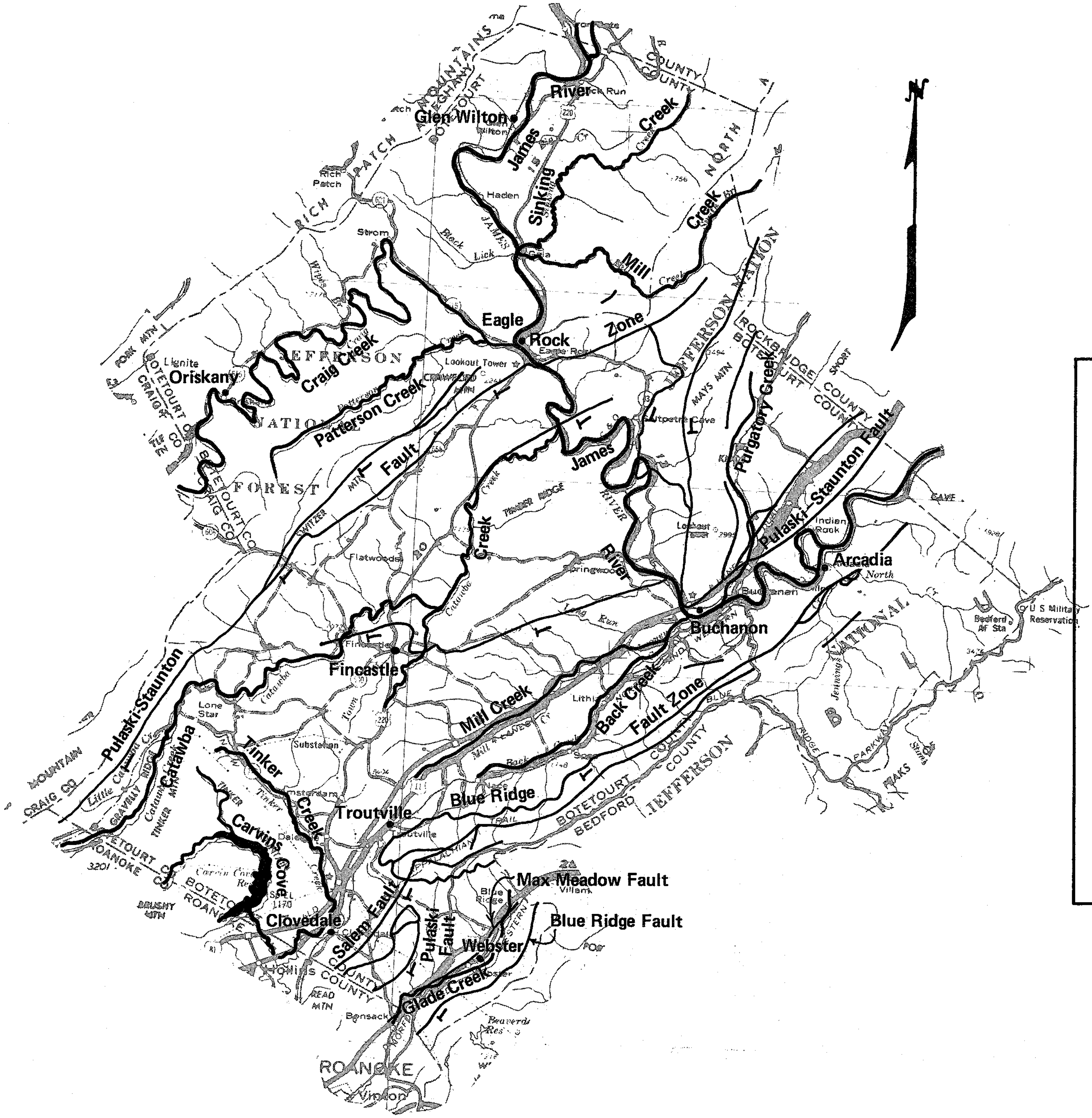


AQUIFERS AND THE HYDROLOGIC CYCLE

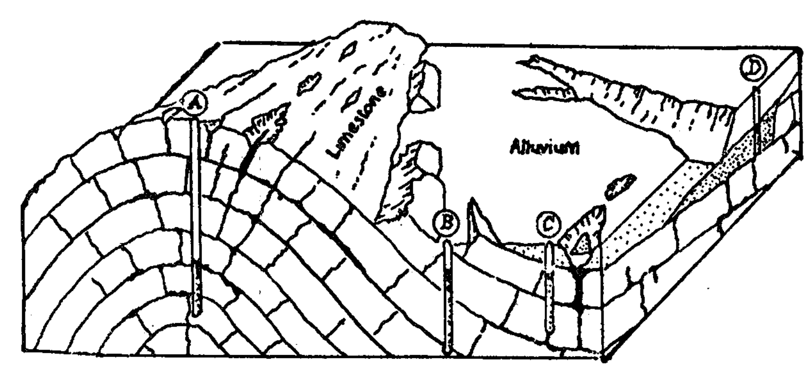
Source: Virginia State Water Control Board-BWCM

PLATE NO. 2

GEOLOGIC STRUCTURES IN BOTETOURT COUNTY



FOLDING AND GROUNDWATER OCCURANCE IN LIMESTONE



Water wells in a region of folded limestone rocks. Dark areas indicate zones with solution openings. Well A is successful but pumping lift is excessive. Well B has a low yield. Well C is successful and has only a small pumping lift. Well D has been developed in alluvium.

Source: Davis and DeWiest, 1966

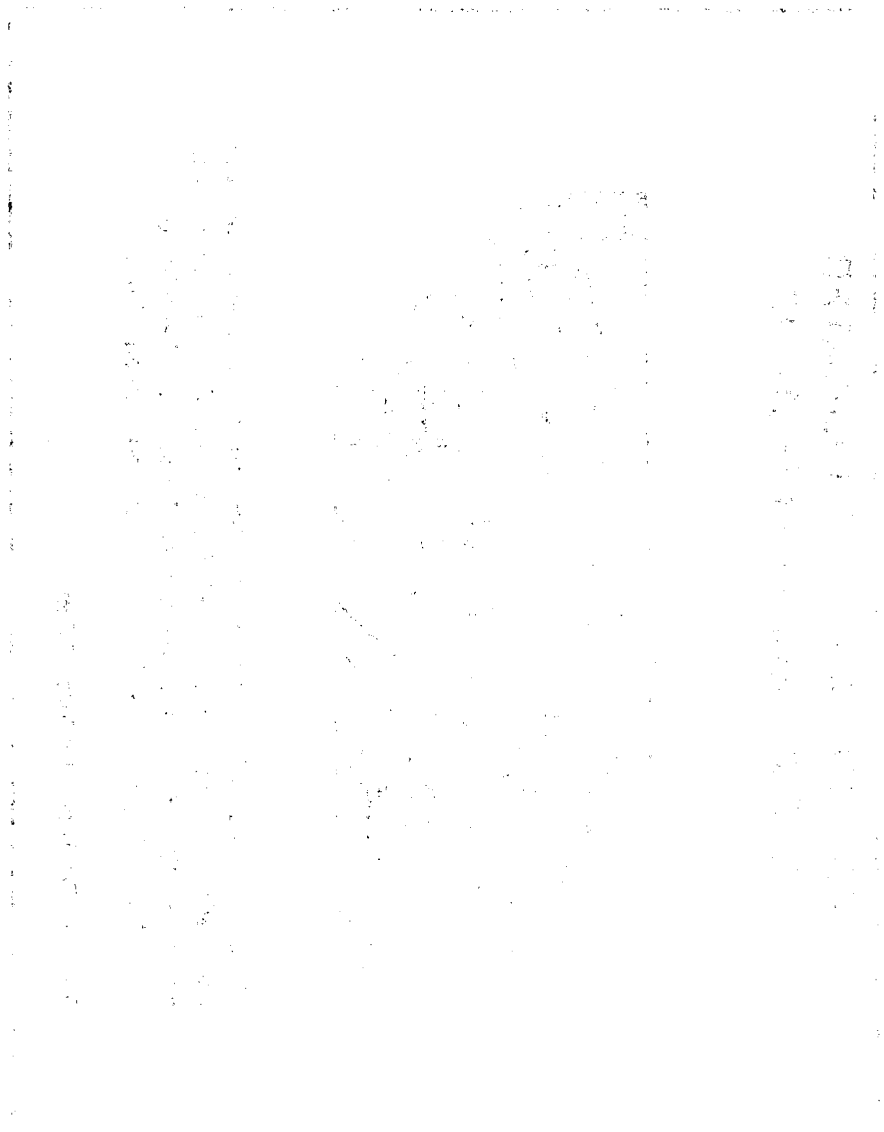
SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: Virginia Division of Mineral Resources

PLATE NO. 3



massive amounts of older rocks have been thrust northwestward over younger rocks. This thrust faulting has created extensive zones of rock breakage and openings in the area of the fault zones, and solution action of groundwater has further enlarged these openings. The major faults that have an appreciable positive effect on groundwater conditions in the County are shown on Plate 3. Rocks in the faulted and folded areas of the County are significantly fractured, expecially within the first two to four hundred feet below the surface, which is favorable to groundwater occurrence and movement.

Geologic Formations and Groundwater Occurrence

The occurrence, nature and average thickness of the rock types introduced above are detailed below as a prelude to discussing groundwater occurrence and availability in Botetourt County.

The nomenclature in this report is consistent with that in Report of Investigations 24, for the Eagle Rock, Strom, Oriskany and Salisbury Quadrangles by Odell S. McGuire published by the Virginia Division of Mineral Resources in 1970. Symbols for the formations appear in parenthesis after each formation. The locations of the rock formations and their water bearing properties are shown on Plate 4, while Plate 5 represents two generalized cross-sections of the hydrogeology of the County, with their locations indicated on Plate 4.

Pre-Cambrian and Cambrian (600 million years old)

The Blue Ridge Complex (p€v) is the name used for various igneous and metamorphic rocks of Precambrian Age which form the core of the Blue Ridge Mountains. These rocks, mainly greenish-gray granite, form the Stuart Knob and Pine Mountain areas of the County. The availability of groundwater in this formation varies greatly. Careful location of wells is necessary to ensure a good yield and reliable source.

Chilhowie Group (Єch) which consists of the Unicoi, Hampton and Erwin Formations is limited to the eastern portion of the County and includes the rocks that support the ridge of mountains extending from Troutville northeast to Rocky Point. They consist predominately of slightly metamorphosed conglomeratic quartzite, sandstone and shale, and have poor water-bearing properties.

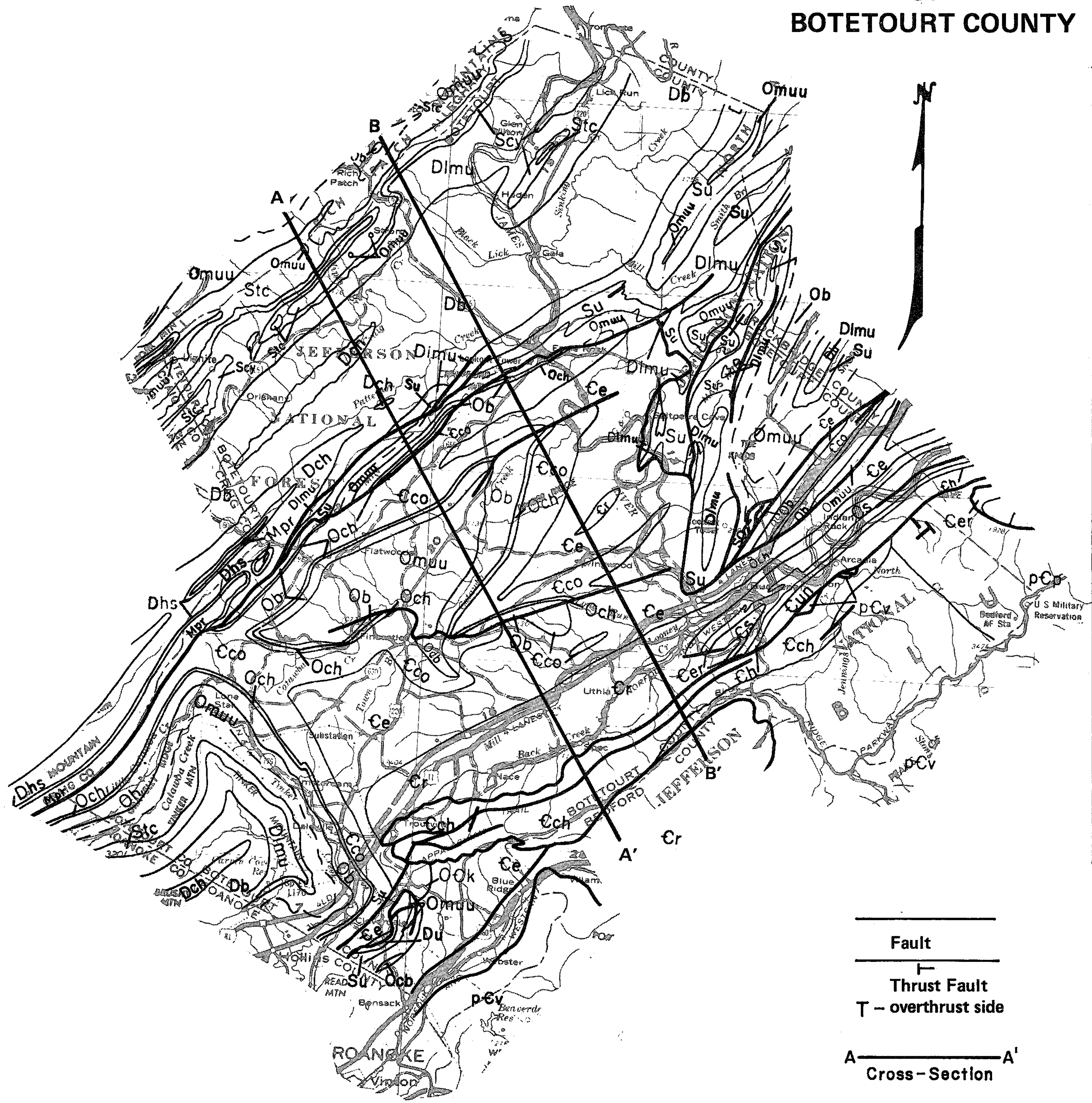
Cambrian (500-600 million years)

The Shady Dolomite (ЄS) occurs in a narrow belt along the eastern portion of the County extending from the Fullhardt Knob area northeast toward Rocky Point. It is a massive, coarse-grained, impure dolomite with interbedded shale and clay. The availability of groundwater in this formation is excellent with high yields frequently encountered.

The Rome Formation (Єr) occupies a belt along the western portion of the Blue Ridge. The Rome is composed of red, green and purple shale which weather to a yellowish-gray color with interbedded limestone, dolomite and sandstone. Dark red shale is the characteristic rock, but only makes up about a third of the exposed formation. The high carbonate content of this formation is responsible for its excellent water-bearing properties in the Coutny.

The Elbrook Formation (Єe) is composed of thin-to-medium bedded dolomite, with some limestone and shale. It occupies a belt west of the Rome Formation, extending to the Fincastle syncline to the west and to the northeast is bounded by the Pulaski-Staunton Fault along the James River. The groundwater availability and reliability is excellent, with high yields frequently encountered.

HYDROGEOLOGIC MAP OF BOTETOURT COUNTY



ERA	SYSTEM		FORMATION—LITHOLOGY (rock type)	WATER PROPERTY
CENOZOIC		Qsq	Quaternary—sand & gravel deposits	Poor to Good
PALEOZOIC	Mississippian	Mpr	Price Formation—shale & sandstone	Poor
	Devonian	Dhs	Hampshire Formation—shale & sandstone, red.	Poor
		Dch	Chemung Formation—shale & sandstone, mostly gray and greenish gray, fossiliferous.	Fair
		Db	Brallier Formation—shale, greenish gray, siliceous; sandstone, greenish, fine-grained, thin-bedded.	Fair
		Dlmu	Devonian Formations, Lower & Middle, undivided—includes New Scotland limestone, Ridgely (Oriskany) sandstone, Huntersville chert, Needmore shale, Millboro shale:	Fair to Good
	Silurian(Su)	Scy	Cayuga Group—includes Wills Creek, Tonoloway and Keyser formations, primarily limestones with some dolomite.	Good to Excel-lent
		Stc	Clinton Formation—shale & sandstone with beds of fossiliferous, hematitic sandstone; and Tuscarora Formation—thick-bedded, quartzite.	Fair
	Ordovician	Omuu	Ordovician formations, Middle and Upper, undivided—includes Elway, Five Oaks limestones, Moccasin, Eggleston, Martinsburg and Juniata Formations; dashed line is at base of Martinsburg Formation	Good to Excel-lent
		OꞒk	Knox Group—includes the Beekmantown Formation (Ob), primarily limestone & dolomite; the Chepultepec Formation (Och)—limestone & dolomite; and the Conococheague Formation (Ꞓco)—limestone & dolomite with beds of sandstone.	Good to Excel-lent
	Cambrian	Ꞓe	Elbrook Formation—dolomite, thick-bedded, shaly, argillaceous, some limestone.	Excel-lent
		Ꞓr	Rome Formation—shale and sandstone, variegated, with dolomite.	Good
		Ꞓs	Shady Formation—dolomite, thick-bedded with some limestone.	Good
		Ꞓch	Chilhowee Group—includes the Erwin Formation (Ꞓer), a thick-bedded, grayish to white sandstone and quartzite; Hampton Formation (Ꞓh)—sandstone, shale & quartzite; and Unicoi Formation (Ꞓun)—conglomerate, shale & quartzite with basalt flows.	Fair to Good
PRECAMBRIAN	pre-Cambrian	pꞒv	Virginia Blue Ridge Complex—greenish gray gneiss, granite; includes the Pedlar Formation (pꞒp).	Poor to Excel-lent

Fault

Thrust Fault
T – overthrust side

A——A'
Cross-Section

SCALE 1:250,000

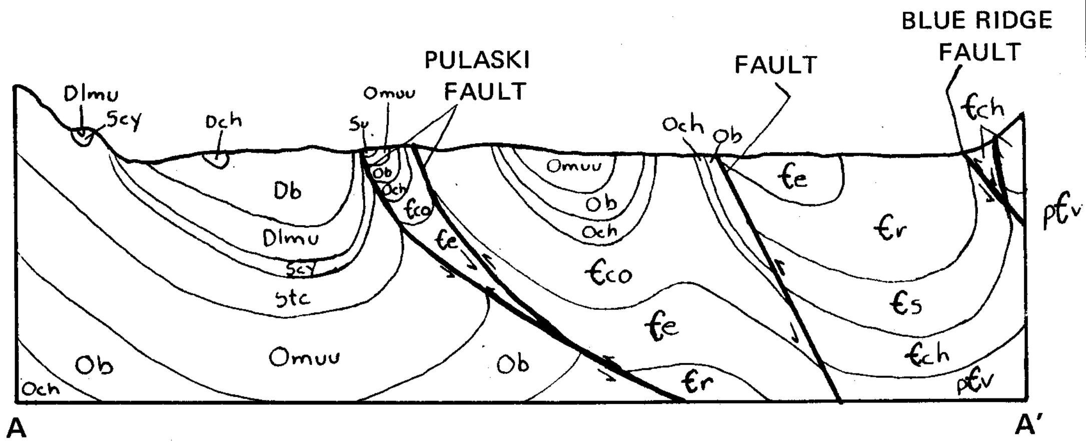
5 0 5 MILES

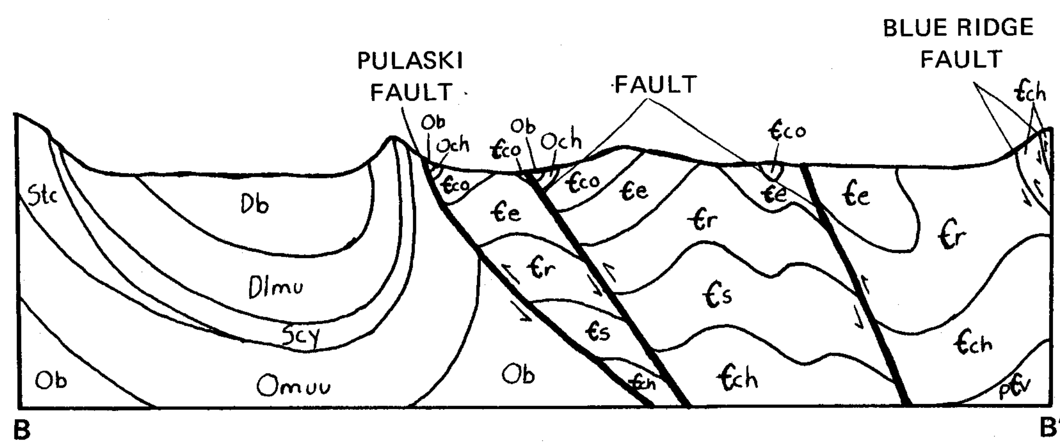
5 0 5 KILOMETERS

Source: Virginia Division of Mineral Resources
Virginia State Water Control Board — WCRO

PLATE NO. 4

GENERALIZED HYDROGEOLOGIC CROSS SECTIONS OF BOTETOURT COUNTY





Vertical Exaggeration: 50x

Scale

5 0 5 miles

5 Km

SOURCE: STATE WATER CONTROL BOARD – WCRO

PLATE NO. 5

Ordovician (425-500 million years)

The Knox Group (OЄK) consists of the Conococheague (Copper Ridge), the Chepultepec Limestone and the Beckmantown Formation.

The Conococheague (Copper Ridge) Formation(Єco) is composed of thin-bedded blue gray limestone with thick-bedded, hard, medium-to light gray sandy dolomite. It occupies a large area in the west central portion of the County, bounded on the west by the Pulaski-Staunton Fault and extends northward to Eagle Rock, southwestward to the Fincastle area, and southeastward to Cloverdale. The water-bearing properties of this formation are good to excellent with high yields often encountered.

The Chepultepec Formation (Och) is a thin-bedded, light-to-medium gray dolomite with some dark blue limestones. It outcrops in a narrow belt around the Fincastle Syncline and farther west in the County along the Pulaski-Staunton Fault Zone. This formation has excellent water-bearing properties, with high yields often encountered.

The Beckmantown Formation (Ob) is a light-to-medium gray dolomite with interbedded gray and dark blue limestone, some with massive white chert beds. It outcrops in the Fincastle Syncline and along the periphery of the Tinker Mountain Syncline (Northeastern extension of the Catawba Syncline), and has good to excellent water-bearing characteristics.

The Edinburg Formation (Oe) consists of medium-gray, fine-grained limestones; black, fissile, silty, calcareous shales with some sandstone and dark gray to black, coarse-grained, fossiliferous limestone. It occurs in the Rich Patch area and in narrow belts in the Fincastle and Tinker Mountain Synclines. The water-bearing properties of this formation are fair to good, but accurate well locations are necessary to obtain reliable yields.

Middle and Upper Ordovician Formations Undivided (Omuu) consists of olive gray to red shale, siltstone, and sandstones, with some conglomerate sandstone and thin-bedded limestone and include the Martinsburg and Bays Formations and the New Market, Lincolnshire and Effna Limestones. This group is exposed in a wide belt in the Fincastle Syncline; north of the James River in the northeastern portion of the County as a small exposure in the Read-Coyner Mountain area and in the Tinker Mountain Syncline (northeastern extension of the Catawba Syncline). Good to excellent water-bearing characteristics feature the the group.

Silurian System (405-425 million years)

Silurian (Su) rocks form most of the crests of the ridges in the western and southwestern portions of the County. Rich Patch, Bearwallow, Tinker, Rathole and North Mountains are some examples within the County where these sandstones are exposed. Very few wells are drilled in this formation, due to its location. The water-bearing properties of the formations are expected to be fair to good, but wells must be accurately located to take advantage of fracturing. For mapping purposes, the Silurian rocks are divided into the:

Cayuga Group (Scy) which includes the Wills Creek, Tonoloway and Keyser Formations, primarily limestones with some dolomite.

Clinton Formation (Stc) composed of shale and sandstone with beds of fossiliferous hematitic sandstone; and Tuscarora Formation which is composed of thick-bedded quartzite.

Devonian System (345-405 million years)

Lower Devonian (Dlmu) undifferentiated rocks consist of coarse-grained sandstones with some conglomeratic beds; dark gray, thin-bedded limestones; white, fine-to-medium grained sandstone and olive green to black fissile shales. These rocks outcrop primarily along the slopes of mountains in the western portion of the County. Water-bearing characteristics are generally poor with some quality problems evident.

The Brallier Formation (Db) consists of olive gray, hard, fissile shale with thin greenish-gray sandstones and siltstones. It occupies a wide belt in the northwestern portion of the County along the Craig Creek and James River valleys. Water-bearing characteristics are generally poor.

The Chemung Formation (Dch) consists of brown, red, tan and greenish gray sandstone, shale and mudstone. It outcrops in the western portion of the County on Patterson Mountain and along the slopes of Price Mountain. Water-bearing characteristics are generally poor.

Mississippian System (310-405 million years)

The Price Formation (Mp) is a succession of shale, sandstone and conglomerate. Much of the upper part of the formation has been removed by erosion. These rocks form the caps of North and Price Mountains. Very few wells are located in this formation because of its location, but generally, its water bearing properties are poor.

Quarternary Unconsolidated Deposits (Present-3 million years) (Qsg)

Unconsolidated deposits of Quarternary Age overlie some of the bedrock geology in Botetourt County. There are three main types present in the County: Colluvium, high-level Terrace Deposits, and present-day Alluvium. The Colluvium is found along the lower slopes of mountains and is composed of material from the rocks that occur on the tops and upper slopes of the mountains, in a matrix of sand and clay. The Alluvium Terrace Deposits occur at the relatively higher elevations along the James River and represent flood plain and channel deposits from previous valley floors. Present day Alluvium (sand, silt, gravel), is presently being deposited along the James River, Craig Creek and Catawba Creek and some of their larger tributaries. The Alluvium Deposits have excellent water-bearing characteristics. Poor water-bearing properties feature the Colluvium and Terrace Deposits.

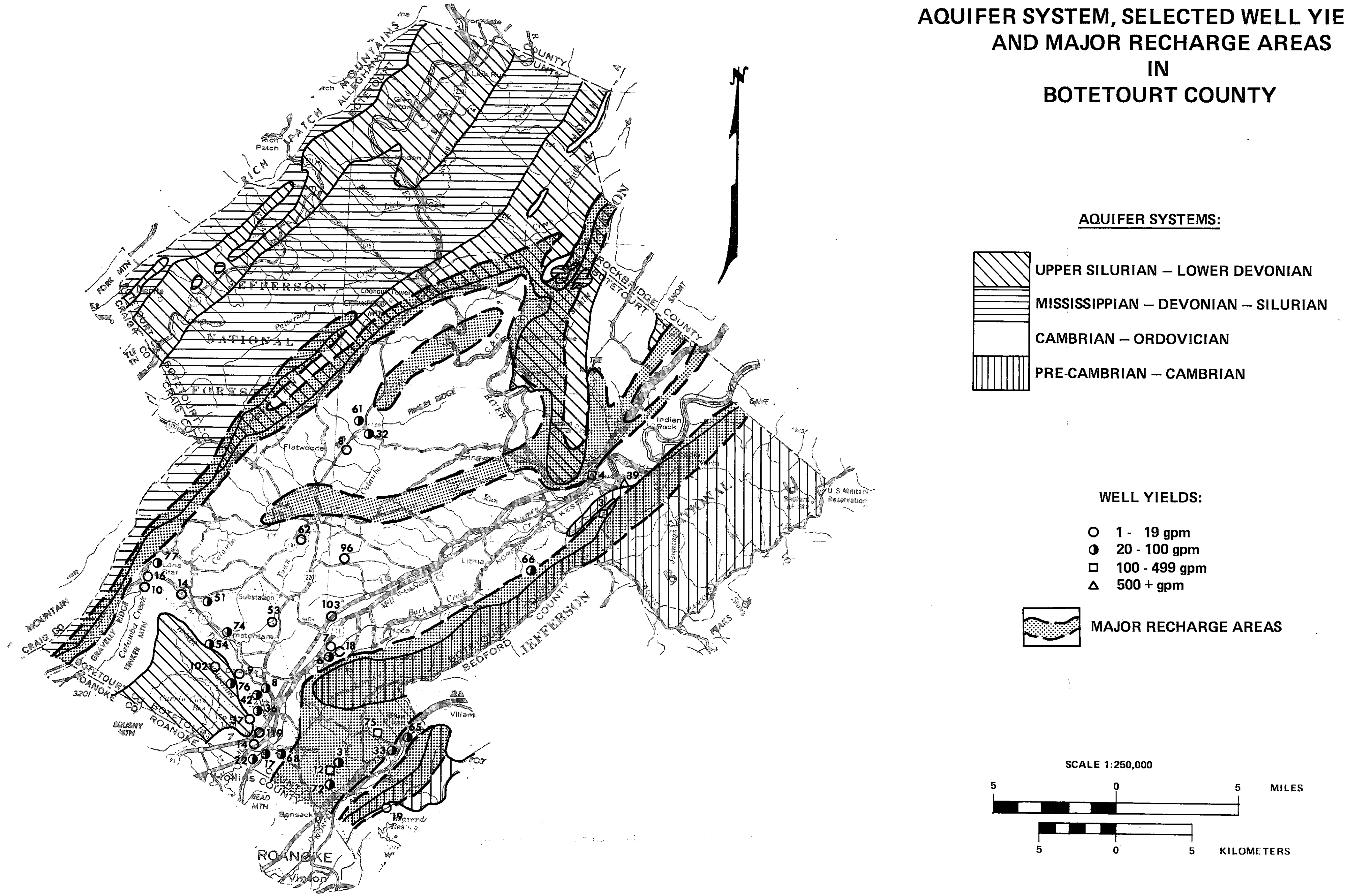
<u>Aquifer Systems</u>

Since many of the geologic formations have similar hydrologic characteristics, the formations are grouped into aquifer systems. Some are very local in nature while others extend over large areas.

Four aquifer systems were defined for this report (Table 2) and their areal distribution is shown in Plate 6, while Plate 4 indicates the occurrence of their geological components. The Cambrian-Ordovician Aquifer Systems (ꞒO-AS) is the best supplier of water in the County in terms of both quantity and quality. The Pre-Cambrian-Cambrian Aquifer System (PꞒꞒ-AS) would be rated second in terms of well yield and water quality while the Upper Silurian-Lower Devonian Aquifer System (USLD-AS), because of its limited extent, would place third. Undoubtedly the Mississippian-Devonian-Silurian Aquifer System (MDS-AS) is the poorest water provider in the County with low well yields and numerous problems with high iron and sulphur concentrations.

<u>The Pre-Cambrian-Cambrian Aquifer System (PꞒꞒ-AS)</u> is composed of metamorphic and clastic rocks from the Blue Ridge Complex and Unicoi, Hampton and Erwin Formations. This system occurs along the extreme eastern portions of the County. Water is stored and transmitted in joints, fractures, fault zones, and contacts between different rock types. The quantities of water in the aquifer system varies widely.

AQUIFER SYSTEM, SELECTED WELL YIELDS AND MAJOR RECHARGE AREAS IN BOTETOURT COUNTY



SOURCE: VIRGINIA STATE WATER CONTROL BOARD – WCRO

PLATE NO. 6

TABLE 2

GEOLOGIC FORMATIONS, AQUIFER SYSTEMS AND THEIR HYDROLOGIC PROPERTIES

IN BOTETOURT COUNTY

Systems	Formation	Lithology (Rock Type)	Thickness in Feet	Aquifer System	Hydrologic Properties
Qsy Quaternary 0-3 Million Years	Alluvium Colluvium Terrace Deposits	Clay,silt,sand and small gravel Blocks of sandstone with sand and clay matrix Coarse gravels, sand and clays	0-120	Not included as a system.	Yield-Excellent in Flood Plain Alluvium,100-400 gpm; poor to fair in Colluvium and higher Terrace Deposits 5-50 gpm. Quality-Generally good in Alluvium, poor in Colluvium and higher Terrace Deposits.
Mpr Mississippian 350 Million years	Price Formation	Tan to light-red sandstone,reddish shales. Lower portion composed of pebbles of white quartz	1800	Mississippian Devonian Silurian MDS-AS	Yield-Fair-good in the valleys; Poor on highest ridges; 2-10 gpm. Quality- Poor-fair especially in the shales, large ares of high iron and sulphur water.
Dhs	Hampshire Formation	Red shale and sandstone.	0-200		
Dch	Chemung Formation	Dark brown sandstone with some olive shales.	2500		
Devonian	Brallier Formation	Grayish shale with interbedded sandstone.	2500		

TABLE 2 cont'd

Dlmu 400 Million Years	Millboro Shale Needmore Formation	Gray to black fissile shale with some sandstone	800-1500		
	Ridgeley Sandstone	Coarse-grained sandstone	300-500		
	Licking Creek Limestone Healing Springs Sandstone Wills Creek Limestone	Succession of dark to light gray, coarse-grained, sandy, cherty, fossiliferous limestone, calcareous sandstone		Upper Silurian Lower Devonian USLD-AS	Yield-Fair to good for most purposes, excellent for domestic use; adequate field investigation required for industrial use, although more than adequate for domestic purposes, 5-25 gpm. Quality-Generally excellent although high hardness values are not uncommon.
	Keyser Formation				
Silurian 440 Million Years	Tonoloway Formation	Dark gray limestone			
Stc	Clinton Formation Tuscaroora Formation	White to reddish sandstone, shale, hematitic sandstone. Thick-bedded quartzite	300-650	Mississippian Devonian Silurian	
	Juniata Formation	Red, fine gravel, sandstone with grayish-red mudrock.	0-250		

TABLE 2 cont'd

Omuu Ordovician 500 Million Years	Martinsburg Formation	Gray shale with with thin-bedded limestone with interbeds of sandstone	1500+	Cambrian- Ordovican Carbonates 60-AS	Yield-Good-excellent for most purposes when high yields are required, adequate field investigations should be conducted to determine the best well location and/or well placement to assure the most efficient development of this aquifer system. Range 15 gpm-500+ gpm. Quality- Generally excellent, moderately hard, isolated areas, contamination induced by man's activities have been delineated. Small isolated areas of high iron, sulfate and extreme hard water exists.
	Middle Ordovician (New Market) (Lincoln Shire) (Effna Limestone) (Fetzer Limestone)	Gray to dark gray massive bedded limestone. Some beds with abundant fossils.	100		
Oe	Edinburg Formation	Dark gray shale and thin-bedded limestone.	970		
O6k	Knox Group	Light gray dolomite with some limestone. Upper portion contains abundance of chert.	1900		
6e Cambrian	Elbrook Formation	Medium bedded dolomite with some limestone and green-gray shales	1000±		

TABLE 2 cont'd

	Rome Formation	Red, green, purple shale and siltstone with beds of limestone and dolomite.	2000±		
Єs	Shady Dolomite	Coarse-grained dolomites with some shales and clays.	1500 ±		
Єch Єer Єh Єun	Chilhowie Group Erwin Formation Hampton Formation Unicoi Formation	Thick-bedded conglomerate, quartzite, dirty sandstone and shale the lower portions basalt	1100 ±		
Pre-Cambrian PЄ 600 Million Years	Virginia Blue Ridge Complex	Greenish-gray gneiss resembles granite		Pre-Cambrian Cambrian Rock PЄЄ-AS	Yield-Poor-good if wells are along fractures; good yiêlds can be had if located on faults. Poor conditions exist if wells drilled on top of hills 2-200 gpm; Quality-Excellent sparse areas of high iron.

The larger quantities are found in areas where the rocks are intensely deformed and fractured and which lie in the lower topographic areas.

Recharge to this aquifer system is local in nature and is accomplished by water percolating slowly through the soil into the openings in the rock, with more recharge taking place in the lower topographic areas. A surface stream crossing a highly jointed or fractured rock strata may loose water to the groundwater regime. The major recharge areas are outlined on Plate 6 and interpretation of this Plate suggests that the western edge of the Pre-Cambrian-Cambrian Aquifer System (P€€-AS) is the only major area of recharge. This large recharge area conforms to the Blue Ridge Fault Zone (Plate 3).

The Cambrian-Ordovician Aquifer System (€O-AS) is primarily composed of limestone and dolomite and contains the rocks of the Shady Dolomite, Rome and Elbrook Formations, Knox group, and the Middle Ordovician limestones. It forms the major valley areas of Botetourt County east of the Pulaski-Staunton Fault.

Recharge to the Cambrian-Ordovician Aquifer System is dependent on soil characteristics, porosity, topography and permeability of the aquifer and the degree of development of vertical fractures in the rock (especially those near the surface). Major recharge zones are shown on Plate 6. Burdon and Papakis (1963) classified infiltration in karst areas (a terrain generally underlain by limestone, in which topography is chiefly formed by the dissolution of rock and is commonly characterized by sinkholes and caves, as is the Cambrian-Ordovician Aquifer System), as diffuse (directly into the ground with little overland flow), or concentrated (capture or diversion of surface streams). The Cambrian-Ordovician Aquifer System is a karst aquifer and receives both types of recharge; however, the majority of recharge in this system is accomplished by diffuse infiltration and is largely dependent on the topography. As the karst land surface becomes more developed (along with the increasing development of the permeability of the aquifer), surface runoff becomes less and less important and diffuse infiltration becomes increasingly significant. The sinkholes serve to funnel precipitation into the ground. There are very few surface streams of any size that are captured and diverted underground in Botetourt County. However, most of the streams which originate on the higher ridges do lose some flow to the groundwater as they meander their way across this system, serving as a source of groundwater recharge.

The movement and storage of groundwater in this aquifer system is highly variable. Groundwater is transmitted and stored in enlarged solution channels which can be thought of as a series of interconnected conduits. The greatest concentration of pipes or openings can usually be located by study of the structural geology of the area, and large volumes of water are stored and transmitted in these highly solutionized zones. The nature of the aquifer system is such that it is hard, with present data, to put a definite figure on the storage capacity; however, large volumes of ground water have been developed and it is assumed that larger quantities could be obtained if the area is studied in detail.

The Mississippian-Devonian-Silurian Aquifer System (MDS-AS) consists primarily of shale and siltstone with some sandstone. It occurs in the western and northern portion of the County with its southern and eastern boundaries being delineated by the trace of the Pulaski-Staunton Fault.

Recharge to this system is accomplished as water percolates through the soil cover and enters openings in the underlying rock. The openings are in the form of small joints, fractures, bedding planes, and fault zones. Recharge is local in nature, that is, the water withdrawn or discharged by a spring probably entered the groundwater regime within relatively close proximity.

Most of this system is composed of shale and siltstone. Shale is highly porous, that is, it can store large quantities of water; however, the permeability (the ability of the water to move) is very low, unless the shale is highly fractured and consequently extraction of the water is difficult. In fact, some of this shale in Botetourt County forms a barrier to the movement of water. Most of the water that is extractable is stored in the fractures and along bedding planes. However, when groundwater inventory is taken for a particular area, this system should not be written off, because the shale feeds a certain amount of water to underlying rocks and adjacent aquifer systems. The sandstones in this aquifer system have fairly good water-bearing characteristics; however, their high elevations significantly reduce recharge potential and subsequent yields from wells are expected to be minimal.

<u>The Upper Silurian-Lower Devonian Aquifer Systems (USLD-AS)</u> consists of the limestones of the Tonoloway, Keyser and New Creek Formations. This system occurs within the boundaries of the Mississippian-Devonian-Silurian Aquifer System in the western and northern portions of the County but has significantly different water-bearing characteristics than that system.

Although this aquifer system has a relatively small areal distribution it can provide adequate supplies of high quality water for most purposes. It is located on the lower slopes of mountains and in some valleys in the western portion of the County and is the primary source of groundwater for domestic purposes in that area. Recharge to the system is similar to that for the Cambrian-Ordovician Aquifer System previously discussed.

The Quaternary unconsolidated deposits which form the flood plains and much of the lower slopes of the mountains in this area, were not included as an aquifer system because these deposits are generally too thin and limited in extent to be a major water-bearing unit, usually less than 50 feet thick, although depths of 100 feet have been recorded along the James River and along the western slope of Reed Mountain. However, wells in Flood Plain Alluvium can yield 100-400 gallons per minute, while those in Colluvium and Terrace Deposits are capable of producing only 5-50 gallons per minute. Also, the Quaternary deposits enhance the groundwater capabilities of the underlying aquifer systems by temporarily storing significant quantities of water, thus allowing a continuous, slow recharge to these systems.

CHAPTER IV

GROUNDWATER QUALITY

Introduction

Both ground and surface water contain a variety of dissolved chemical constituents which affect their overall quality and usefulness. Frequently, surface water has a greater variety and higher concentration of dissolved constituents because many factors can affect its quality, while groundwater quality is usually dependent upon the soil and rock in which the water occurs. Man's activities have a significant and immediate impact upon surface water quality while, in most cases, the impact on groundwater quality is not as immediate, although the effect may be much more severe in the long run.

General Groundwater Quality

As mentioned above, the natural dissolved chemical constituents in groundwater are primarily derived from the soil and rock in which the water occurs and, subsequently, these constituents and their concentrations will vary from one area to another dependent upon the geology of these areas. Generally speaking, groundwater is colorless, clean and has a constant temperature equivalent to the average yearly temperature of the region where it occurs (in Botetourt County, about 56 degrees F.)

Numerous properties can be determined by detailed water analysis techniques, however, eight parameters are usually sufficient for the overall assessment of the groundwater quality in Botetourt County. Results of these analyses are usually expressed in the metric weight system as either parts per million (ppm) or milligrams per liter (mg/l). Although not precisely equivalent, these terms are used interchangeably in describing water quality analyses. A water quality analysis that exhibits an iron (Fe) concentration of one ppm, indicates that the water has one unit weight of iron for every million unit weights of water; thus this water would contain one pound of iron for every million pounds of water. This same relationship holds true if the analysis is expressed in milligrams per liter (mg/l) since one million milligrams are in a liter.

The Virginia State Department of Health (Waterworks Regultions,1974), which is responsible for the potability of water, has delineated public drinking water standards for certain chemical constituents. The list is comprehensive and requires testing for chemical, bacteriological, and radiological constituents before a source can be approved as a public drinking water supply. However, the parameters discussed below (public drinking water standards are listed in parenthesis when applicable), provide an adequate picture of groundwater quality for domestic, industrial, and commercial purposes. Although not discussed below, public drinking water standards also delineate concentrations for such heavy metals as arsenic (0.1 mg/l), barium (1mg/l), cadmium (0.01 mg/l, chromium (0.05 mg/l), copper (1 mg/l), cyanide (0.2 mg/l), lead (0.05 mg/l), mercury (0.002 mg/l), silver 0.05 mg/l) and zinc (5 mg/l). With the exception of copper and zinc, the limits listed above are based on the toxicity of the various metals and provide a reasonable safety factor for human consumption. Groundwater quality in Botetourt County is generally excellent except as noted later in this Chapter under Groundwater Problems.

Hardness. Water hardness is primarily derived from dissolved calcium and magnesium (although other dissolved constituents contribute to the total hardness value) and is most commonly evidenced by the amount of soap required to produce suds which will not form until the dissolved minerals are removed from the water. The insoluble scum, recognized as the familiar bathtub ring, that is produced is the result of the combining of the soap and dissolved minerals. In addition, when "hard" water undergoes drastic temperature changes, the calcium and magnesium will precipitate in the form of a white scale and may cause problems in hot water heaters and lines, household appliances (e.g. coffee percolators), industrial boilers and other devices that appreciably raise water temperature.

Calcium and magnesium (or carbonate) hardness is generally the major portion of total water hardness and may be reduced by boiling or through household water softeners. Other dissolved elements also contribute to water hardness and cannot be reduced by boiling, although they usually do not present a significant problem. Household water softeners can be adapted to treat this portion of the total water hardness.

The degree of water hardness is relative between different areas where water is consumed. Generally speaking, water with hardness values less than 50 ppm is considered soft, while values up to 150 ppm are not uncommon in carbonate aquifer systems and are usually not objectionable for most purposes (Johnson, 1972). Hardness values above 150 ppm become increasingly noticeable and some sort of softening process is commonly utilized for domestic and industrial purposes. Hardness values of 100 to 150 ppm can cause considerable boiler scale and, when utilized, municipal water supplies are generally softened to reduce these values to about 85 ppm (Johnson, 1972).

<u>Hydrogen Ion Concentration (pH)</u> Measurement of the pH of the water

gives an indication of whether the water will act as a weak acid or as an alkaline solution. Water with a pH value below the neutral value of seven is considered acidic, while pH values above seven indicate that the water is slightly alkaline. Acidic water will tend to corrode metals that come in contact with it (e.g., well casing, pumps, water line, etc.). In areas with acid mine drainage, improper disposal of chemical wastes and other activities that may pose a threat to groundwater quality, determination of pH values may indicate contamination of groundwater.

Total Dissolved Solids (500 mg/l) A general indication of the water's overall suitability for many uses is given by the concentration of total dissolved solids present. Water with concentrations less than 500 ppm total dissolved solids is generally satisfactory for domestic use and for many industrial applications. Water with concentrations in excess of 1,000 ppm total dissolved solids is generally unsuitable for most purposes, having a disagreeable taste and being potentially corrosive to well screens, casing and pumping apparatus (Johnson,1972).

Iron (0.3 mg/l) Iron is contained in practically all water supplies and when present in even small quantities, may present considerable problems when used for domestic or industrial purposes. The limit mentioned above is based primarily on the suitability of the water for domestic and industrial purposes. Excessive amounts of iron can cause problems with staining on plumbing fixtures and during laundering, incrustations of well apparatus and the plugging of pipes. The presence of iron in well water favors the growth of iron bacteria which precipitates iron in a sheath that surrounds their bodies and can cause extreme problems in clogging of the pores in water bearing formations, pump screens, and plumbing fixtures.

The problem with high iron concentrations is closely related to its complex chemistry when dissolved in water. Iron dissolved in water will tend to precipitate as iron oxide (rust) when it comes in contact with air. In many cases, water with high iron concentrations will be clean when pumped, but after the water comes in contact with air, the water may become a little cloudy as the iron begins to precipitate out of solution. After the iron has precipitated, a small amount of rust colored material may be noticeable in the bottom of a container or, if conditions permit, a slight film will develop on the water. In cases where iron concentrations are low, preventing aeration of the water should minimize the formation of the iron precipitate. When high concentrations of iron are present, treatment for removal of this iron may be the only solution, although it is generally difficult and costly.

Manganese (0.05 mg/l) Manganese is very similar to iron in regards to its behavior and occurrence in groundwater, although manganese staining is more annoying and harder to remove. Manganese bearing water also favors the growth of a slime forming bacteria and may cause similar problems with clogging of pumping apparatus while at a much lower concentration than iron. As is the case with iron, preventing aeration of the manganese bearing water will minimize the precipitation of an insoluble manganese residue.

Chloride (250 mg/l) Chloride is the primary constituent of a variety of salts; for example, common table salt is sodium chloride (NaCl). Higher concentrations than drinking water standards will give the water a salty taste and the corrosiveness will markedly increase. Water with chloride concentrations of 500 mg/l or higher will usually have a disagreeable taste; however, studies indicate that livestock such as cattle may be able to consume water with 3,000 or 4,000 ppm of chloride with no ill affects (Johnson, 1972). High concentrations of chloride in groundwater usually indicates contamination of the aquifer by sea water (in coastal areas), salt brines (common in many gas and oil producing areas) or from some of man's surface activities such as highway deicing or salt storage areas.

Sulfate (250 mg/l) The occurrence of sulfate in groundwater is principally derived from gypsum (calcium sulfate) or from the oxidation of pyrite (iron sulfide). The public drinking water standard is based primarily, on asethetic considerations. Concentrations as high as 750 mg/l can be tolerated; however, if manganesium sulfate (Epson salt) or sodium sulfate (Glauber's salt) are present in sufficient amounts, infrequent users may notice a laxative effect (Johnson, 1972) and the water will have a bitter taste.

Nitrate (10 mg/l as Nitrogen) The concentration of nitrate in groundwater may vary significantly from one area to another, and its presence appears to be unrelated to geology. Nitrate content in soil can be attributed to many sources such as type of vegetative cover (alfalfa and soy bean plants add nitrogen to the soil), use of fertilizers, land disposal of sewage treatment plant effluent and sludges, animal wastes and septic tank fields, to mention a few. As water percolates through the soil, it will remove the organic nitrogen present in these wastes and transmit it into the groundwater regime. High concentrations of nitrate in well water is an indicator that the water should be tested for the presence of harmful bacteria that could also have been transported into the aquifer system from these sources.

Water analyses usually indicate concentrations of the nitrate ion (NO_3) as elemental nitrogen. The public drinking water standard for nitrate is established due to the possible toxicity to infants from higher concentrations. This toxic effect, known as cyanosis, causes the baby to become listless and drowsy, with his skin taking on a blue color and may result if water containing excessive nitrate is used in preparation of the baby's formula.

Groundwater Quality in Botetourt County

Groundwater quality in Botetourt County is generally very good, although high hardness, iron and sulphur values are not uncommon in certain areas. Appendix A is a detailed water quality data printout for specific wells in the County for which reliable information is available. Review of Appendix A reveals that groundwater quality for each aquifer system is generally the same for specific wells. Table 2 presents the average groundwater quality for each system and while relatively good quality is present, variances between aquifer systems do exist.

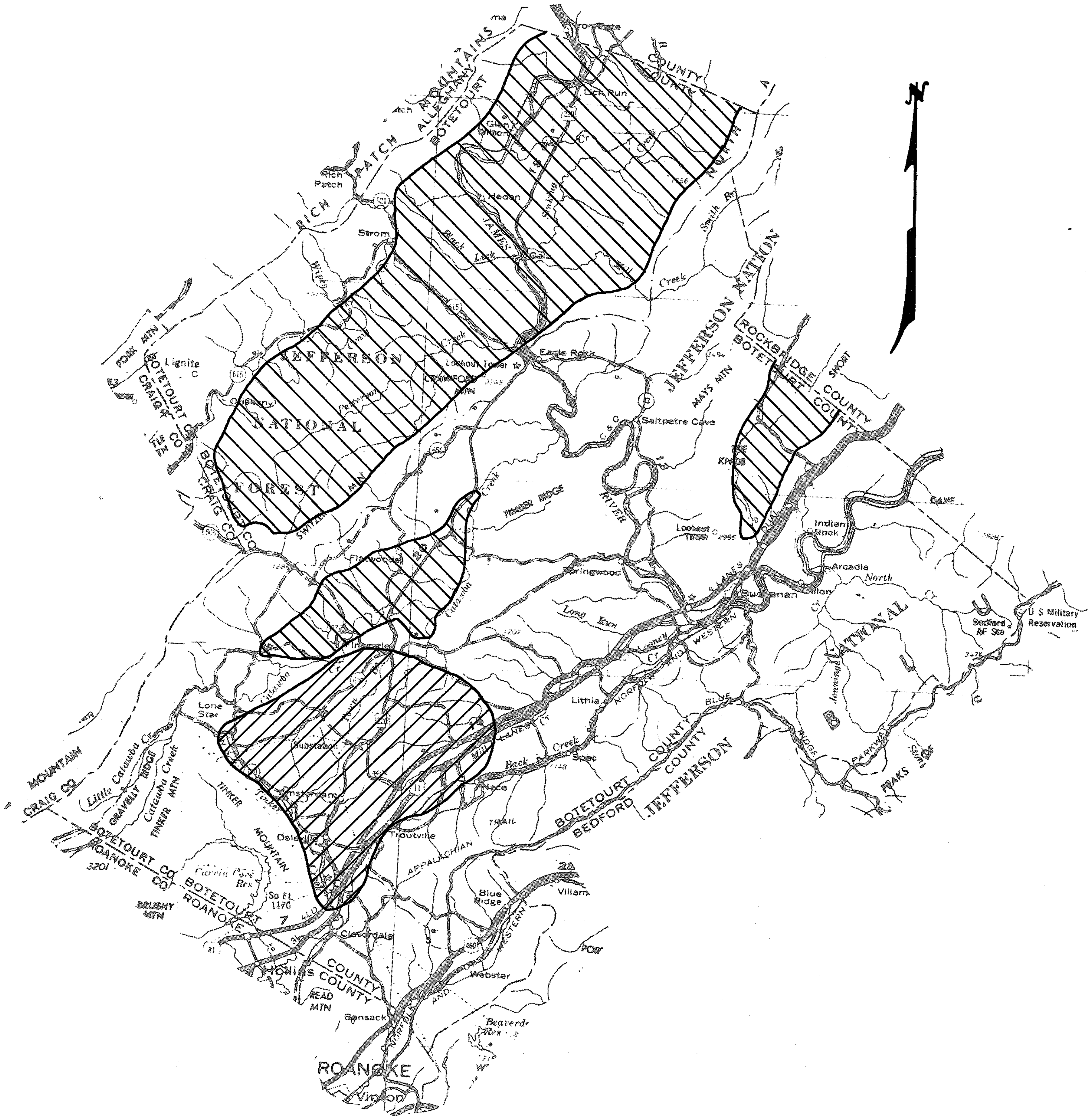
Groundwater quality is greatly affected by the rock type in which the water occurs. The aquifer systems in Botetourt County encompass several different rock types and because of this, a discussion of water quality according to aquifer system is presented below:

Pre-Cambrian-Cambrian Aquifer System. At present, no quality data is available for this system, because the majority of the area within this system is National Forest Land and therefore, is sparsely populated and wells are rare. However, data from the same aquifer system in Roanoke County indicates that in general water from this system is of good quality. In some isolated instances, however, unacceptable iron and manganese concentrations do occur. It is expected that similar conditions exist in the Botetourt portion of the aquifer. It should be emphasized that most wells will have iron and manganese concentrations well within acceptable limits and that only in unusual cases will excessive iron be encountered.

Cambrian-Ordovician Aquifer System. The majority of rock types in this system is limestone and dolomite which can result in very high hardness values, because of the dissolution of calcium and magnesium by the groundwater. Hardness values in excess of 250 mg/l are not uncommon although the range is generally 135 mg/l to 225 mg/l. The general trend of hardness values is shown on Plate 7. Excessive amounts of sulfate present in the water are derived from certain geologic formations in the aquifer system. The general trends of abnormal amounts of iron and sulphur water are noted on Plate 7. Mineralization along faults and fractures occur in areas that have undergone the tremendous pressures involved in mountain building and in some instances, iron-bearing water has been found; however, this is not the general case.

Mississippian-Devonian-Silurian Aquifer System. This system, due to its geologic history, may have water which presents problems with excessive iron, manganese, and sulfate concentrations. Although it is difficult to predict if a certain well location will encounter water with these problems, it can generally be stated that water from this system has higher concentrations of iron, manganese and sulfate than other aquifer systems in Botetourt County. Plate 7 gives a general picture of area where it is not uncommon to encounter high iron and sulphur concentrations. While uncommon, occasional pockets of trapped methane gas have been encountered while drilling in this system. The

GROUNDWATER QUALITY AREAS FOR BOTETOURT COUNTY



LEGEND:

(blank)	NO SIGNIFICANT PROBLEMS, ALTHOUGH OCCASIONAL UNACCEPTABLE GROUNDWATER QUALITY MAY BE ENCOUNTERED
(hatched ///)	EXTREMELY HIGH HARDNESS VALUES ARE COMMONLY ENCOUNTERED
(hatched \\\\\\)	HIGH IRON AND SULPHUR CONCENTRATIONS COMMONLY EXIST

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD – BSFS

PLATE NO. 7

TABLE 3

AVERAGE GROUNDWATER QUALITY ACCORDING TO AQUIFER SYSTEMS

IN BOTETOURT COUNTY

Parameter	MDS-AS	USLD-AS	ЄO-AS	PЄЄ-AS
pH	7.4	7.5	7.4	7.0
T.D.S.[2]	176	202	265	117
Hardness	154	190	271	68
Iron	*	0.1	0.16	0.12
Manganese	*	*	*	0.02
Chloride	2.0	*	5.43	4.6
Sulfate	5.2	1.8	26.1	2.8
Nitrate	3.1	2.5	5.6	8.85

1. All values expressed in milligrams/liter (mg/l) except for pH.
2. T.D.S.-Total Dissolved Solids

Note: MDS-AS: Mississippian-Devonian-Silurian Aquifer System
USLD-AS: Upper Silurian-Lower Devonian Aquifer System
ЄO-AS: Cambrian-Ordovican Aquifer System
PЄЄ-AS: Pre-Cambrian-Cambrian Aquifer System

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

gas is a result of decomposition of organic matter contained in shale of member formations in the system, and through folding of the bedrock pockets of gas may be trapped in small cavities and anticlinal structures.

Upper Silurian-Lower Devonian Aquifer System . This aquifer system which occurs in the western portion of the County and consists predominately of limestone, portrays significantly different water quality than does the Mississippian-Devonian-Silurian Aquifer System. Hard water is not uncommon, average hardness being 190 mg/l, however, this water is generally of excellent quality.

Alluvium, Colluvium and Terrace Deposits. From the standpoint of quality, water from these unconsolidated deposits does not compare to that from the four previously described aquifer systems. Although these deposits can provide abundant quantities of water, it should be remembered that they were "recently" laid down by streams and rivers, with which they are hydrogeologically connected and as a consequence, water in them is parent to surface water and may have similar quality problems. Since these deposits are on the surface of the land with minimal soil cover (if any) the water they contain is subject to quality problems akin to the waters of streams and rivers. However, the deposits constitute a filter, which should generally result in an improvement in the quality of their water with respect to that of the streams and rivers.

Man's Influence on Groundwater Quality

Surface water exists in a fairly "open" system, that is, factors influencing water quality rapidly contaminate the water, detection is fairly immediate and degree of severity is usually short-lived.

Groundwater, however, exists in what can be termed a "closed" system, that is, input to the system is screened by percolation through overlying materials. Movement in one groundwater area is relatively slow when compared to surface water velocities. Therefore, when contaminants reach groundwater, the contamination is likely to be in that particular area for quite awhile, and detection will take place after a long interval.

Detection of contaminated groundwater is not as immediately apparent as for surface water. Man's surface activities can proceed for years with no noticeable effects on groundwater quality and suddenly appear as a relatively severe pollution problem. For example, an automotive garage may dispose of its waste oil by dumping it out back of the facility for years, with no groundwater quality problems evident. However, it may take years for the oil to slowly percolate down through the overlying soil cover and through the bedrock, to appear, quite suddenly, in a neighbor's well. When something like this occurs, it is very difficult, if not impossible, to correct the situation.

Man's activities may result in a much swifter impairment of groundwater quality than the above example. In carbonate areas, sinkholes provide and solution cavities permit, easy access and rapid transmission of contaminants in the groundwater regime. Poorly constructed water wells are another means for rapid contamination of groundwater by permitting surface water to flow down the well casing and into the groundwater regime.

Practically all of man's activities have the potential for adversely affecting groundwater quality. Large urban areas where much of the land surface is covered by concrete and asphalt can locally affect groundwater recharge by preventing percolation of water through the soil zone and into the groundwater regime. Subsurface disposal of storm water run-off, such as used in the Williamson Road area of Roanoke City, may cause groundwater contamination problems due to the pollutants that are picked up by the water prior to its disposal.

The capacity of soils for filtering and treating waste products generated by man is generally good; however, if careful consideration is not given to the planning, design and construction of land disposal areas, groundwater contamination may result. Sanitary landfills, chemical waste disposal areas, sludge disposal areas, and land application of sewage treatment plant effluents, to mention a few, all require adequate planning and operation to assure that groundwater quality in the area is maintained. Many cases throughout the country have been documented where groundwater contamination has been detected 25 to 50 years after a land disposal site has been abandoned. Experience has shown that with present technology, rehabilitation of contaminated aquifers is extremely difficult and very expensive.

In addition to land disposal of wastes, other surface activities can seriously effect groundwater quality in a particular area. The improper or excessive use of fertilizers, pesticides, herbicides and larvaecides, deicing salts or accidental spilling of petroleum products have a severe and long lasting potential for groundwater contamination. It must be recognized that prevention of groundwater contamination is the key to maintaining groundwater quality and that rehabilitation of contaminated groundwater resources is very difficult, if not impossible, to attain.

Groundwater Problems

Groundwater in Botetourt County can provide a relatively abundant and trouble free source of high quality water for most purposes. Besides differences in the quality of groundwater in the previously discussed aquifer systems, other isolated problems with groundwater have been defined in the County, although not extensive in their nature, some of the problems discussed below can have severe consequences in specific areas of the County.

Water Levels

A water well in an aquifer is analogous to a straw in a glass of water except that the glass of water does not receive any recharge and the aquifer does. As water is removed through the straw, the water level in the glass declines until the glass is empty. However, if the glass was supplied with a flow of water equal to the rate of withdrawal from the straw, the water level in the glass would remain the same. A similar situation occurs in an aquifer system with a well withdrawing water from it. If the withdrawal rate is equal to or less than the recharge to the aquifer, the water level in the aquifer will remain the same, although a cone of depression may be developed in the immediate area of the well because the permeability of the rock will not permit an instantaneous flow of water to the well.

When wells or well fields are pumped in excess of the recharge rate to an aquifer system, the water level in that system will decline. However, this is not the case in Botetourt County even though groundwater supplies 100 percent of the water needs, because the total use of groundwater is small compared with the availability of groundwater. As future water demand is supplied by groundwater, proper development and management of wells and well fields should be employed to prevent water levels decline, dewatering of aquifer systems and well interferences to insure conservation of groundwater resources.

Pollution

Inadequate well construction is perhaps the most common factor in groundwater contamination; usually the contamination is localized and is the result of polluted surface water flowing down the sides of the well casing and entering groundwater where the casing is not properly sealed. If wells are properly constructed, i.e. use of sufficient grouting and adequate well casing, contamination of the groundwater supply will be minimized. Subsurface disposal by septic tank fields and pit privies is the most common waste treatment methods employed in Botetourt County. Approximately 1,000,000 gallons of sewage per day is discharged in the above manner at the present time. Care must be taken to assure that adequate soil depth and characteristics are present to sufficiently treat these wastes and thus avoid groundwater contamination.

Many of man's surface activities have the potential for severe and long term groundwater contamination. Septic tanks, sanitary landfills, open chemical storage centers, highway deicing activities, sludge disposal areas, industrial waste disposal areas, underground storage tanks and most any other activity where toxicants are placed on the land surface have the potential for groundwater pollution. In most cases, contamination of the groundwater is not immediate, but rather has a long incubation period before detection and once discovered, may continue for long periods of time. Only by implementation of preventative measures including proper construction techniques and operational controls, can groundwater quality be assured.

Hydrocarbon Contamination, Town of Fincastle

Hydrocarbon contamination of about 16 wells in the Town of Fincastle was dectected over a period of approximately three months. The sources that produced the hydrocarbon contamination seemed to be of two origins; 1.) during the process of bringing a fire in the Town under control, large quantities of hydrocarbons were washed into a low-lying area termed as a sinkhole, 2.) over a period of years, the careless disposal of used motor oil. Apparently when the Virginia Department of Highways & Transportation started construction of U.S. 220, the blasting, etc., started the hydrocarbon moving.

The Town is in the process of now constructing a central water system, tapping another aquifer system to supply water for the citizens of the Town.

Sanitary Landfills

Several sanitary landfills and numerous abandoned dumps exist in Botetourt County. The sanitary landfills provide a needed and useful service to the community and it is through adequate planning and operation that groundwater contmaination will be prevented. The active sanitary landfill for Botetourt County does have two observation wells to monitor groundwater quality. This will give needed data on the operation of the landfill and the suitability of sites over a prolonged period of time.

With the passage of Federal and State requirements for disposal of solid waste, emphasis has been placed on all phases of landfill operations to minimize the impact of such an operation on the environment in regard to both surface water and groundwater.

CHAPTER V

GROUNDWATER DEVELOPMENT AND POTENTIAL

Introduction

The water requirements for private, public and industrial purposes within Botetourt County are currently being fulfilled by the abundant groundwater resources of the County. Several factors have contributed to the preference of groundwater development as opposed to utilizing surface water resources. Some of these factors include: 1.) development and treatment costs are approximately three to five times less for groundwater than for surface water; 2.) greater than 90 percent of the potable water is underground; 3.) the population distribution throughout the County is such as to favor the development of groundwater resources over construction of surface water impoundments; and 4.) industries within the County are located in a rural environment which lacks a central water supply of sufficient capacity to meet their needs and, consequently, groundwater totally supplies the industrial needs of the County.

Review of current data indicates that the potential for groundwater development is very large and that groundwater will be able to meet the needs of the County in the years to come.

Groundwater Development

In Chapter III, four aquifer systems were defined in Botetourt County and their areal distribution indicated on Plate 6. Table 4 represents current groundwater usage in Botetourt County for public, private and industrial water supply systems. The figures listed in Table 4 represent the current use, but not the present level of groundwater development in the County. Present groundwater development expressed in terms of specific well yields, can be found in Appendix B, which is a water well data summary printout. Such information as depth, casing size, static water level, yield and water bearing zones are listed for individual wells. Tabulation of well yield information indicates that approximately 7.4 MGD of groundwater have been developed and could be extracted if so desired. This printout does not list information for all wells within the County and the figure for present groundwater development is estimated to be in the vicinity of 10 MGD.

TABLE 4

GROUNDWATER USAGE IN BOTETOURT COUNTY

Owner	Average Usage (GPD)	Population Served	Estimated Percent Withdrawal from Each Aquifer System	
Public System	904,560	11,307	USLD-AS	1%
Industrial	25,000	---	MDS-AS	16%
Private	538,510	7,693	CO-AS	75%
			P€€-AS	8%
	1,483,070	19,000		100%

It should be noted that this represents development and not usage. The large variance between usage and development indicates that tremendous quantities of groundwater are available for use by municipalities, industries and individuals.

Appendix B provides useful information for existing or potential groundwater users. By examining this printout and studying the information on wells with the same general location, one can obtain an overall picture of what will be involved in developing groundwater in a particular area. Locations of specific wells are not listed in Attachment B. However, this information can be obtained from the State Water Control Board upon request.

Water well site selection may be accomplished by different methods or be the result of the combination of various modes of investigation. Hydrogeologists utilize topographic and geologic maps and interpretation of aerial photographs in combination with field investigation. In many instances, the water well driller may have sufficient experience in a particular area to find a suitable well site for domestic purposes. However, users requiring high yields should obtain professional consultation or investigate the feasibility of exploratory drilling prior to committing themselves to a particular well location.

There are many different water needs ranging from single home dwellings to large industrial users. Commonly, they are broken down into three categories: Domestic, Public and Industrial.

Domestic Supplies. Domestic supplies or private systems are those which have less than 15 connections or less than 25 people on a single well (Virginia Department of Health). This type of system includes most all of the rural areas of the County. For a single home dwelling one commonly needs at least 1.5 to 6 gpm to have a reliable water supply. After property is acquired, the first thing a citizen should do is obtain a water supply before any construction starts. There have been many cases where water was not found because the well location was selected for convenience sake and not in consideration of hydrogeologic factors.

Public Supplies. A public system defined by the Virginia Department of Health includes all wells which have fifteen or more connections or 25 or more people on one well. In Botetourt County approximately 33 public systems are supplying approximately 904,560 GPD to about 11,307 citizens. Development of groundwater for public supply systems is desirable for many reasons; for example, quality is generally very good and subsequent treatment costs are kept to a minimum. In addition, large reservoirs are not required, provided adequate well yields are obtained. If one or two wells are not sufficient to supply water needs, development of a well field which utilizes several wells,spaced at intervals of 200-400 feet, should provide an adequate water supply with a minimum of surface land area required for treatment facilities. Since groundwater percolates down through the soil cover, developers of public supplies must take precautions to prevent contamination of groundwater by septic tank effluents or other means.

Industrial Supplies. Data taken from Virginia State Water Control Board files indicates that there are at least 4 industrial users of groundwater in Botetourt County. The largest user is withdrawing approximately .03 million gallons per day (MGD). These large users are located along major tributaries or are in very close proximity to fault zones in the County and consequently, development in these high production zones provides a high quality, economic source of water.

Groundwater Potential

Many factors influence the potential that may be obtained from a particular area or aquifer system. Due to the hydrogeologic characteristics of the four previously described aquifer systems, it is not possible to determine the water storage capabilities of these systems. However, the same factors that make such an estimation impossible, also permit very high yields to be developed within the individual aquifer system, provided proper exploration, conservation, and development techniques are used in conjunction with sound management principles.

As mentioned earlier, Table 4 presents a general idea of current water usage from the various aquifer systems. Present development of these systems is reflected in Appendix B, however, examination of well information listed in the appendix, will reveal that most wells are the same diameter. This fact indicates that maximum development of the well was not undertaken in most instances.

Yields for domestic supplies are generally below the yields that could be developed from a particular well because when a sufficient yield for domestic purposes is obtained (usually 1.5 to 6 GPM) drilling is terminated. Consequently the potential of a particular well site is not fully explored and the true production capabilities are not determined. In addition, domestic well locations are generally chosen for convenience sake and not with respect to obtaining maximum yield.

When significant quantities of water are required, the potential development of groundwater should be thoroughly investigated. This investigation should include development measures such as increasing well size (for example, to 12 or 16 inches), installation of well fields and well locations with respect to geologic factors. For example, large yeilds can be developed in close proximity to major folds, faults, and fracture traces. If particular problems have been encountered in a particular area in the past, users requiring significant amounts of water may want to employ exploratory well drilling in an effort to estimate development potential.

Plate 3 indicates the major geologic structures in Botetourt County. Numerous faults are present in the County and, it is along these faults and associated fractures, that very high yields can be obtained. With proper location, well size and development, yields in excess of 500 gpm could be expected along the major fault zones in the County. It must be emphasized that, for very large yeilds, professional consultation should be obtained prior to drilling.

CHAPTER VI

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Findings

This report provides a generalized picture of the groundwater resources of Botetourt County and discusses the factors influencing its quality, occurrence, availability, potential and development. Although the report is centered on the manifold aspects of groundwater, it should be noted that a direct relationship exists between surface water and groundwater resources, because some water that occurs on the surface will eventually become groundwater and vice versa. Surface water provides recharge to the groundwater regime, and during periods of low surface water flows, groundwater sustains surface water streams. Therefore, the intimate relationship between groundwater and surface water must be recognized and considered when evaluating the water resources of Botetourt County.

Current data on file with State agencies indicate that groundwater in Botetourt County has been utilized in small proportion to its potential, and that future water needs can be met by the abundant good quality groundwater of the County. However, hardness and iron problems must not be overlooked in certain areas.

Many of the geologic formations in the County have similar water-bearing characteristics, and thusly, the formations were grouped into four major aquifer systems: 1.) the Pre-Cambrian-Cambrian Aquifer System (P€€-AS), is located along the eastern portions of the County. The water-bearing properties vary from poor to good depending on whether a well is located along faults and fractures where good yields are obtained. Water quality is excellent except for sparse areas of high iron and manganese; 2.) the Cambrian-Ordovician Aquifer System (CO-AS) forms the major valley areas in the County, east of the Pulaski-Staunton Fault. The water-bearing properties are good to excellent. This aquifer system is the most productive in the County, and the quality of water in this system is generally excellent; 3.) the Mississippian-Devonian-Silurian Aquifer System (MDS-AS) is found in the western portions of the County. Fair to good water yeilds are available in the valleys, poor conditions on the higher ridges. High iron and sulphur concentrations can be found in certain areas; and 4.) the Upper Silurian-Lower Devonian Aquifer System (USLD-AS) is found within the boundaries of the MDS-AS, although it has considerably different hydrologic characteristics. It is composed of predominately limestone and in general, water quality is excellent and availability good.

At present, approximately 1.5 million gallons per day of groundwater is being withdrawn for public and industrial uses, primarily from the Cambrian-Ordovician Aquifer System. Most important in developing the present and future groundwater needs in the County is the realization that groundwater is a delicate and vulnerable resource which deserves adequate protection, conservation and management if it is to fulfill its potential as an abundant high quality and economical water supply. Man's activities (such as mining, waste injection, septic tanks, disposal wells, and the like) can have severe effect on groundwater since wastes are being or have the potential of being introduced to the subsurface with subsequent contamination of groundwater, which is especially difficult and expensive to restore.

Man made groundwater quality problems are very isolated in the

County. The most significant problem is from hydrocarbon contamination in the vicinity of the Town of Fincastle. The potential for groundwater contamination is present at sanitary landfills in the County, although, monitoring of the groundwater quality around these facilities has not indicated any problem to date.

Natural groundwater quality problems with high hardness, iron and sulphur concentrations have been delineated in the various aquifer systems discussed in this report. Although it is difficult to predict if an individual well will have quality problems, certain areas of the County are more prone to have problems than others.

Conclusions

One of the most significant natural resources of Botetourt County is the groundwater. This resource is predominantly of very good quality that is barely developed and utilized at the present time. Although it is difficult to predict what the potential for development is for any one aquifer system, it is conservatively estimated that an additional 80 million gallons per day could be developed from the aquifer systems in the County. Areas of large groundwater potential are present in the County for future municipal and industrial growth.

Recommendations

With future development in the County, care must be taken to prevent groundwater contamination. Although the County is presently rural in nature, future industrial and municipal growth must not be allowed to contravene the high quality of the groundwater.

Groundwater needs to be recognized as a valuable natural resource and accurate studies conducted to obtain optimum utilization of this resource. For example, with accurate investigation, large well fields located in high groundwater potential areas could be constructed to supply a significant portion of the industrial and municipal growth.

Subdivisions and multiple-unit housing developments should have community services that provide central sewerage with development of groundwater for individual or community supplies. At the present time, central water supplies are stressed with individual household sewage disposal being accomplished through septic tank fields. This leaves groundwater open to contamination by inadequately or improperly installed disposal systems. The potential for groundwater contamination could be greatly reduced or eliminated if central sewerage service were the primary service offered by the developers.

APPENDIX A

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR BOTETOURT COUNTY

The computer printout on the following pages lists basic groundwater quality data available for many of the wells listed in the water well data summary (Appendix B). There are some quality analyses listed for wells not included in Appendix B; however, well data is available for these wells and may be obtained by contacting the State Water Control Board's West Central Regional Office in Roanoke or the Headquarters Office in Richmond.

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR BOTETOURT COUNTY

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THE FOLLOWING LIST OF GROUNDWATER QUALITY DATA SUMMARIZES BASIC DATA OBTAINED FROM ANALYSES OF GROUNDWATER, COLLECTED FROM WELLS AND SPRINGS, WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL GROUNDWATER QUALITY INFORMATION FOR MANY OF THESE WELLS AND SPRINGS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF SURVEILLANCE AND FIELD STUDIES AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL.

DATE SAMP: DATE SAMPLED - MONTH AND YEAR IN WHICH WATER SAMPLE WAS COLLECTED.

PH: HYDROGEN ION CONCENTRATION - BASED ON A SCALE OF 1 THROUGH 14, WATER WITH A PH GREATER THAN 7.0 IS CONSIDERED TO BE BASIC OR ALKALINE; THE LARGER THE PH VALUE, THE MORE ALKALINE THE WATER. WATER WITH A PH LESS THAN 7.0 IS CONSIDERED TO BE ACIDIC; THE SMALLER THE PH VALUE, THE MORE ACIDIC THE WATER.

SPEC COND: SPECIFIC CONDUCTIVITY - AN INDICATOR OF THE RELATIVE AMOUNT OF DISSOLVED MINERALS IN WATER; HIGHER VALUES INDICATE GREATER AMOUNTS OF DISSOLVED MINERALS; UNIT OF MEASUREMENT IS MICROMHO

T-DIS SOLID: TOTAL DISSOLVED SOLIDS - INDICATES TOTAL AMOUNT OF DISSOLVED MINERALS IN WATER; UNIT OF MEASUREMENT IS MILLIGRAMS PER LITER

HARDNESS TOTAL: TOTAL HARDNESS - CAUSED BY THE PRESENCE OF CALCIUM, MAGNESIUM, IRON, ZINC , AND OTHER TRACE METALS. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

HARDNESS CA,MG: CALCIUM-MAGNESIUM HARDNESS - INDICATES THAT PORTION OF TOTAL HARDNESS CAUSED BY CALCIUM AND MAGNESIUM, WHICH ARE GENERALLY RESPONSIBLE FOR ALMOST ALL HARDNESS IN WATER. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

THE AMOUNT OF HARDNESS IN WATER WILL AFFECT THE ABILITY OF SOAP TO LATHER OR CLEANSE BECAUSE OF THE TENDENCY OF THE IONS CAUSING HARDNESS TO REACT WITH SOAP. THE HIGHER THE HARDNESS OF WATER, THE MORE DIFFICULT IT IS FOR SOAP TO LATHER.

NOTE: TOTAL HARDNESS IS GENERALLY DETERMINED BY CHEMICAL TITRATION WHEREAS CALCIUM-MAGNESIUM HARDNESS IS GENERALLY DETERMINED BY MATHEMATICAL CALCULATION FROM CHEMICALLY-DETERMINED VALUES FOR CALCIUM AND MAGNESIUM. BECAUSE OF THIS DIFFERENCE IN DETERMINATION, THE CALCIUM-MAGNESIUM HARDNESS VALUES FOR SOME ANALYSES WILL BE LARGER THAN THE TOTAL HARDNESS VALUE.

******** PARAMETERS LISTED BELOW ARE MEASURED IN MILLIGRAMS PER LITER ********

FE: IRON	MN: MANGANESE	CA: CALCIUM
MG: MAGNESIUM	NA: SODIUM	K: POTASSIUM
HCO3: BICARBONATE	SO4: SULFATE	CL: CHLORIDE
	NO3: NITRATE (AS NO3)	

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR BOTETOURT COUNTY

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
1	MAYHEW SUBDIVISION	6 63	7.6				176	0.03	0.00	38.1	19.7			210	0.1	0.8	0.4
2	MAYHEW SUBDIVISION	7 63	7.6				142	0.00	0.00	31.8	15.9	3.3		181	0.7	2.1	3.5
3	TOWN OF BUCHANAN #1	7 63	7.5				148	0.00	0.00	34.0	15.3	39.0		148	0.2	3.4	0.0
4	TOWN OF BUCHANAN #2	7 63	6.8				89	0.00	0.00	22.0	8.2	39.0		110	0.4	1.8	13.3
6	FIELD UNIT #25 WELL #2	4 67	6.5		48	35	24	0.08	0.07	8.0	1.1	0.0			0.5	1.0	0.4
7	FIELD UNIT NO 25	4 67	6.5				25	0.08	0.07	8.0	1.1			44	0.5	1.0	1.8
8	TOWN OF DALEVILLE	1 64	6.9					0.11	0.00					445	371.5	45.0	62.0
9	WILLIAMSBURG COURT	3 64	7.3					0.05	0.00					342	190.8	5.7	0.4
12	RAINBOW FOREST #2	10 64	7.6				230	0.22	0.07	51.3	24.7	11.3		265	4.0	2.6	2.7
13	RAINBOW FOREST #3	3 65	7.5				169	0.07	0.00	38.9	17.6			196	6.3	1.3	2.2
14	OBS WELL #14	2 72	7.4	490	275		250	0.04		68.0	20.0	2.4	6.0	302	16.0	3.8	8.0
14	OBS WELL #14	10 69	7.8	370	201		183	0.00		42.0	19.0	2.6	3.9	200	20.0	5.2	12.0
16	LONE STAR CEMENT CORP	3 64	7.1					0.00	0.00					268	18.7	2.5	6.6
18	VDH,TROUTVILLE	4 67	7.9				189	0.14	0.02	40.9	21.2			176	0.5	34.5	3.1
29	VA DEPT OF HIGHWAYS	11 75		790		338	370	0.10	0.00	76.0	44.0	20.0	0.7		2.2	144.0	
32	H A GROSS INC	1 76	7.1	350	251	184	196	0.80	0.31	61.0	10.8	10.0	0.5		36.5	3.0	0.0
33	STRADFORD PLACE	1 76	7.6	250	176	140	148	0.00	0.10	35.0	14.8	1.0	1.6		9.1	2.0	0.9
40	VA DEPT OF HIGHWAYS	11 75	7.5	620		324	363	0.00	0.00	75.0	43.0	3.0	4.5		11.0	32.0	3.5
40	VA DEPT OF HIGHWAYS	6 63	7.8		194	149	137	0.00	0.00	30.4	15.1				0.7	1.0	
41	JAMES RIVER HIGH SCH	11 75	7.8	350		230	246	0.00	0.01	51.0	29.0	1.0	0.9		14.6	1.0	0.0
41	JAMES RIVER HIGH SCH	11 75		390		208	228	0.00	0.00	47.0	27.0	1.0	1.0		12.0	2.0	
41	JAMES RIVER HIGH SCH	12 74	7.5	344		228	284	0.00		76.0	23.0	0.9	1.4		12.0		0.0
46	BOTETOURT INTERM SCH	2 76	7.2	440	302	237	249	0.10		72.0	17.1	14.0	1.1		55.6	11.0	0.4
62	E B MORGAN (INSIDE)	2 76	7.0	650	398	349	433	0.10		111.0	38.0	6.0	2.0		18.6	11.0	9.7
62	E B MORGAN (OUTSIDE)	2 76	7.4	560	357	231	345	56.00		113.0	15.4	6.0	1.4		13.4	13.0	0.4
47	EAGLE ROCK ELEM SCH	11 75	7.6	450		226	260	0.00	0.00	93.0	6.8	1.0	0.4		12.1	8.0	17.7

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR BOTETOURT COUNTY

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
47	EAGLE ROCK ELEM SCH	11 75		500		228	259	0.00	0.00	93.0	6.7	5.0	0.5		11.7	8.0	
55	WHITE OAK ESTATES #1	4 66	7.4				154	0.13	0.05	33.1	17.4			179	9.6	0.5	0.9
56	WHITE OAK ESTATES #2	4 66	7.2				564	1.46	0.30	136.9	54.2			542	119.1	1.0	1.8
57	DALECOURT	1 64	6.9					0.10	0.00					337	18.5	4.9	48.3
59	DALEVILLE FARMS (SP)	6 63	7.2				396	0.00	0.00	104.9	32.5	13.3		315	115.0	5.5	30.1
60	FOREST LAKE SUB (SP)	1 64	7.4					0.01	0.00					144	1.2	1.7	4.0
61	DAYS CONSTRUCTION CO	1 76	6.9	220	165	130	115	0.40	0.06	34.0	7.5	8.0	0.3		18.9	5.0	0.4
69	BLUE RIDGE WATER CO	1 76	7.8	470	290	280	304	0.00	0.00	61.0	37.0	6.0	0.6		9.8	3.0	4.0
71	ROBERT E WOOLWINE	2 76	7.1	570	339	358	450	0.00		80.0	61.0	6.0	1.7		10.6	6.0	3.5
73	RUNAWAY VILLAGE	9 73	8.1	208	148	129	133	0.09	0.00	39.0	8.7	1.9	1.3		1.4	3.0	7.1
78	I D LAYMAN	4 74	7.4		353	352	172	0.00		36.0	20.0	3.0	1.8			14.0	
79	MRS J W ELLER	4 74	7.7		364	344	224	0.00		7.7	50.0	3.5	1.7			1.0	12.0
81	CORRECTIONAL UNIT	4 74	6.9		58	4	64	0.00		13.0	7.9	2.3	2.0		0.8	2.6	0.0
82	SP GW12 NEAR LANDFILL	4 74	7.4		176	154	172	0.00		36.0	20.0	3.1	1.7		5.2	2.0	3.1
83	N K BREEDING	4 74	7.6		272	276	299	0.00		54.0	40.0	5.0	2.1		10.4	4.0	7.1
84	QUALITY STATION GW14	6 74	7.5	310	198		208	0.00		44.0	24.0	1.0	0.2			2.0	2.7
84	QUALITY STATION GW14	4 74	7.6		205	194	172	0.10		36.0	20.0	1.7	0.2		1.8	0.0	2.2
86	BOTETOURT FOREST	5 74	8.0	205		110	152	0.00		38.0	14.0	3.2	1.7		1.8	2.0	1.8
87	G A DOOLEY	5 74	7.6	665		384	562	0.00		110.0	70.0	11.0	0.8		18.5	11.0	0.4
88	RAINBOW FOREST	4 76	7.0	600		379	317	0.00	0.00	81.0	28.0	6.0	23.0		228.0	2.0	0.0
88	RAINBOW FOREST	5 74	8.0	507	342	290	356	0.00		77.0	40.0	4.2	1.8		138.0	1.0	0.9
89	FINCASTLE SPRING	5 74	7.3	750	463		364	0.00		90.0	34.0	14.0	25.0			19.0	34.6
90	TOWN OF EAGLE ROCK	11 75	7.3	460		180	271	0.00	0.00	98.0	6.6	1.0	0.0		12.1	3.0	4.4

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR BOTETOURT COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
90	TOWN OF EAGLE ROCK	11 75		410		398	214	0.00	0.00	78.0	4.8	1.0	1.0		10.6	9.0	
91	MRS D S FROST	8 74	7.0	270	155		164	0.60		40.0	15.8	1.3	2.2			0.0	2.7
92	QUALITY STATION GW91	8 74	8.3	355	209		232	0.10		52.0	25.0	1.3	1.4			1.0	0.0
93	COLING BAPTIST CHURCH	1 75	7.5	440		262	256	0.00	0.00	74.0	17.4	3.4	1.2		5.9	4.0	0.0
94	E Z SERVICE	1 74	7.6	230		122	129	0.00	0.00	32.0	12.0	0.8	1.5		1.8	2.0	0.9
95	CASH SUPPLY CO	1 75	7.4	540		310	344	0.10	0.03	115.0	13.9	7.0	0.0		29.0	36.0	0.4
96	FRANK FARMER JR	1 76	7.3	540	351	332	363	0.10	0.00	73.0	44.0	3.0	1.6		16.1	2.0	2.7
97	TOWN OF BUCHANAN	11 75	7.8	410		256	259	0.00	0.00	43.0	37.0	1.0	1.3		19.1	10.0	0.0
97	TOWN OF BUCHANAN	11 75		440		238	240	0.00	0.00	42.0	33.0	1.0	1.3		18.7	2.0	
98	DAIRY BOTETOURT	8 74	6.9	350	222		216	0.20		51.0	21.6	2.8	6.5			18.0	10.6
99	C M PAXTON	8 74	7.5	255	156		165	0.10		35.0	19.0	1.1	1.4			1.0	8.0
100	CRAWFORD	8 74	6.3	110	72		57	0.10		14.0	5.5	0.9	1.9			1.0	0.9
101	J T LEONARD	8 74	7.2	210	130		132	0.20		33.0	12.1	0.2	5.6			1.0	0.4
103	R S RANDOLF	1 76	7.8	628	395	326	406	0.10	0.00	97.0	40.0	1.0	1.1		5.3	3.0	3.5
112	MRS JAMES BOOZE	5 74	7.5	780	474		385	0.00		87.0	41.0	11.0	11.6			19.0	19.9
113	FINCASTLE SPRING	8 74	7.8	490	463		305	0.20		114.0	5.1	6.9	0.6			12.0	14.6
114	TOWN OF EAGLE ROCK	8 74	7.3	360	275		226	0.10		83.0	4.7	4.1	1.4			5.0	4.4
115	BOTETOURT EAST	4 76	7.2	250		151	138	0.00	0.00	43.0	7.6	8.0	0.8		10.8	2.0	0.0
115	BOTETOURT EAST	5 74	7.7	231	133	114	141	1.60		44.0	7.8	5.0	2.1		8.0	3.0	0.0
116	CEMENT PLANT	5 74	9.8	186	91	72									16.4	12.0	0.9

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

APPENDIX B

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

The computer printout on the following pages lists basic well data for wells in Botetourt County. This printout is updated frequently to include information from new Water Well Completion Reports which are constantly being submitted by water well drillers.

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

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THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH "GEOLOGIC MAP OF VIRGINIA" (DIVISION OF MINERAL RESOURCES - 1963)

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
1	HENRY R MAYHEW	58	D		250	70	6				CE	50	15			2	PUB
2	HENRY R MAYHEW	62	D		320	100	6				CE	110	15	200	.07	6	PUB
3	TOWN OF BUCHANAN				376	5	8				CS		200				PUB
4	TOWN OF BUCHANAN	57			472	296	8				CE	200	130	10	13.00	30	PUB
5	M H COOPER	64			230	42	5				CE	80	20				DOM
6	FIELD UNIT #25	66	D G		220	218	6				ALLUV	100	11	100	.11	36	INS
7	FIELD UNIT #25	62	D		190		6		96	156	ALLUV	35	7	100	.07	30	INS
8	DALEVILLE WATER CO	63			120		6				OMUU	45	35	10	3.50	4	PUB
9	B W HOPKINS	63	D		343	78	6				OMUU	30	12				PUB
	WILLIAMSBURG COURT																
10	LONE STAR CEMENT CORP	62	D	1320	160	5	8				OMUU	19	6	1	6.00	24	ABD
11	BLUE RIDGE HEIGHTS				374	85	6				CR						PUB
12	RAINBOW FOREST WTR CO	65	D G		260	90	6				CE	20	150	100	1.50	2	PUB
13	RAINBOW FOREST WTR CO	64	G		140	49	6				CE	50	60	130	.46	5	PUB
14	OBSERVATION WELL #14	67	D	1340	399	4	7				ORDOV	4	18	275	.06	8	GOV
	UNIVERSAL ATLAS																
15	UNIVERSAL ATLAS CEMEN	67	D	1340	264	5	7				ORDOV	18	1				ABD
16	LONE STAR CEMENT CORP	57		1315	315	5	8					25	9				IND
17	PATTERSON & AILSTOCK	73	D		225	91	8	6			CE		45	157	.28	72	PUB
	DEV.- CLOVERDALE FM																
18	VA DEPT OF HIGHWAYS	66			365	50	5				CR	94	9			2	GOV
19	MARTIN BROS CONTRCS	69			105	80	6					85	10			2	DOM
20	J E CAMPBELL	69			140		6						12			4	COM
21	SHELL OIL CO	68	G		124						CCO						COM
22	OASIS WATER CO				170	90	8					20	40			36	PUB
	ROSEMAE GARDENS																
23	TINKERVIEW GARDENS				647		6				CE						PUB
24	TINKERVIEW GARDENS				111		6				CE						PUB
25	MAYFORE WATER CO	69			165		6				CE	50	90			24	PUB
26	VA DEPT OF HIGHWAYS	52	D	1080	64	5	6				OMUU	11	15				GOV
27	EAGLE ROCK WTR CO (SP										CE		50				PUB
28	TROUTVILLE WATER CO	61			300	17	8				CR	70	75			160	PUB
29	VA DEPT OF HIGHWAYS	70	D		600		7				CR	20	8	580	.01	8	ABD
30	R D STONER	71			365		7				CE		3				IND
31	RAINBOW FOREST WTR CO				255		8				CE						PUB
32	H.A. GROSS, INC.	73	D		185	22	6				CCH		50			2	PUB
33	TEMPO HOMES	74			450		8					75	55	242	.22	48	PUB
	STAFFORD PLACE SUB																
34	BOTETOURT IND DEV AUT	71	D		65		6				CE						ABD
35	TINKERVIEW WATER CO	69			185		6				CE		200			2	PUB
36	BOTETOURT IND DEV AUT	71	D		165		6				OMUU		20				IND
37	BOTETOURT IND DEV AUT	71	D		245	60	6				OMUU		15				IND
38	DEMONSTRATN WTR PROJ	71	D		400		6				OMUU		60	300	.20	5	PUB

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
39	JAMES RIVER HYDRATE	64			260	35	6					59	750	25	30.00	1	IND
40	VA DEPT OF HIGHWAYS	70			418		6				OMUU	10	8	365	.02	24	GOV
41	JAMES RIVER HIGH SCH	58			328	17	6				CE	65					INS
42	LORD BOTETOURT SCH	58			336	2	6				OLN	67	30	175	.17		INS
43	BRECKINRIDGE ELEM SCH	51			160						OMUU	48					INS
44	CLOVERDALE ELEM SCH	53															INS
45	COLONIAL ELEM SCH	39			108						CE						INS
46	BOTETOURT INTERM SCH	58			140	70	6				OLN						INS
47	EAGLE ROCK ELEM SCH	26			132						CE	72					INS
48	GLEN WILTON WTR CORP										USLD		1300				PUB
49	BAPTIST CH,CLOVERDALE	72	D		85	3	6				OMUU		12			2	DOM
50	ETZLER BROS	72	D	1440	425						CCO						DST
51	ETZLER BROS	72	D	1460	225	7	6				CCO		50			1	IND
52	ETZLER BROS	72	D	1460	285						CCO						DST
53	BOTETOURT ELECTRIC CO	72	D	1490	205	12	6				CE		6			2	DOM
54	WILLIAM F GREENWAY	72	D	1250	85	15	6						20			2	DOM
55	BLUE RIDGE HTS CORP										CCH						PUB
56	BLUE RIDGE HTS CORP										CCH						PUB
	WHITE OAK ESTATES																
57	DALE COURT WATER CORP				119		6				CR	8					PUB
58	DALEVILLE WATER CO										CR						PUB
	DALEVILLE FARMS																
59	DALEVILLE WATER CORP																PUB
60	FOREST LAKE WTR CORP										CE						PUB
61	DAYS CONSTRUCTION CO	72	D		125	10	6				CCH		30			2	IND
62	DR E B MORGAN	72	D	1440	500	25	6				CCO		15			1	DOM
63	J L MAYHEW	72	D		225	20	6						3			2	DOM
64	JOHN CONE	72			600		6					100	6	500	.01	12	PUB
65	JOHN CONE	72			600		6					100	18	500	.03	12	PUB
66	ROY COCKRILL JR	72	D		145	58	6				CCH		30			3	COM
67	BOTETOURT FOREST INC	72			200		8				CE	42	55	86	.63	51	PUB
68	JAMES E LONG	72			380		8				CE	22	60	43	1.39	72	PUB
69	DEMONSTRATION WTR PRO	73	D		305	1	6				CCH	59	25	130	.19	49	PUB
70	TINKERVIEW SWIM CLUB	73	D	1325	400	10	6				CCR		25			3	PUB
71	ROBERT E WOOLWINE	73	D	1280	305	14	6						6			2	DOM
72	IUAN M. GREEN	73		1100	185	15	6						50			2	PUB
73	C R SIMPSON, INC.	73	D		190		6					97	55	2	27.50	60	PUB
74	DALLAS T BYRD	74	D	1400	405		8						20			2	PUB
75	BURRESS LAND & LUMBER	74	D		265		10	8			CCH		300			2	PUB
76	MR B WILLIS HOPKINS	74	D	1320	125		6				MDS		75			4	PUB
	WILLIAMSBG C& WT CO																
77	GEOTECHNICS, INC	74	D	1260	148		10	6			OLN		100			3	IND
	CITADEL CEMENT																
78	I D LAYMAN																IND
79	MRS. J W ELLER																IND
80	MURRY'S ORCHARD																IND

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
81	CORRECTIONAL UNIT																IND
82	NEAR BOTETOURT LNDFLL										CR						IND
83	N K BREEDING										CR						IND
84	QUALITY STATION GW14																IND
85	G E HOLT																IND
86	BOTETOURT FOREST										CE						IND
87	G A DOOLEY																IND
88	RAINBOW FOREST										CCH						IND
89	FINCASTLE SPRING										OCH						IND
90	TOWN OF EAGLE ROCK	74			385		8						60	232	.25	48	PUB
91	D S FROST																PUB
92	GW-91																PUB
93	H F HOGAN			1280													DOM
94	E-Z SERVICE			1260													DOM
95	CASH SUPPLY CO			1150	104		6					12	30	18	1.66	2	PUB
96	FRANK FARMER JR	75	D		550	15	6					70	6			4	DOM
97	TOWN OF BUCHANAN	74	D		610	80	8				CE	70					PUB
98	RT 653 DAIRY																PUB
99	C M PAXTON																PUB
100	CRAWFORD																PUB
101	J T LEONARD																PUB
102	RICHARD A BEERMAN	75	D		157		6					20	8				DOM
103	CHARLES MCNEILL	75	D		225	82	6					125	10				DOM
109	BOT CO NURSING HOME				175						CCH	97				72	INS
110	BOT FOREST SUB HOME																PUB
111	K F IKENBERRY				120		6				CE		20				PUB
112	MRS JAMES BOOZE																PUB
113	FINCASTLE SPRING										OCB						PUB
114	TOWN OF EAGLE ROCK										CE						PUB
115	BOTETOURT EAST SUBDIV										CE						PUB
116	CEMENT PLANT										OLN						PUB
117	K A PATTERSON	75	D		445		8						20			4	COM
118	BLUE RIDGE WATER AGEN										CE		30				COM
119	FIFTH PLANNING DIST	75	D		190	47	6						5			1	COM
120	REED MT WATER CO	75	D		345	95	8				CE	94	100			4	PUB
121	RUTH H SAUNDERS	75	D		65		6						20			2	DOM
122	C L SHOWALTER	75	D		285	17	6						10			2	DOM
123	H E MAXEY	75	D		225		6						12			2	DOM
124	REED MT WATER CO	75	D		350						MDS						PUB
125	H A GROSS INC	75	D		245								100				ABD
126	EDDIE BOY STEVENS	75	D		210		6					30	6				DOM
127	NATIONWIDE MFG CO	75	D		305		6						1				DOM
128	NATIONWIDE MGF CO #4	75	D		305		6						1			4	DOM
129	JOSEPH R HUFFMAN	75	D		345		6						3			2	DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR BOTETOURT COUNTY

****

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
130	PATTERSON & AILSTROCK	75	D		105		6						20			2	DOM
131	GEORGE HALE	75	D		125		6						4			1	DOM
132	BOTETOUT FOREST INC.	76	D		245	95	8	6				164	60			48	PUB
133	RAINBOW FOREST WATER	76			300	40	10	8				191	43	273	.15	48	PUB
134	RAINBOW FOREST WATER	76			265	20		8				34	35	210	.16	48	PUB
135	ELIZABETH V. WILSON	76	D		85	15		6					7				DOM
136	H.M.DUDLEY	76	D		185	65		6					20			2	DOM
137	JAMES SLOCUM	76			142	66		6				40	10				DOM
138	W.C.RONK	76			145	23		6				45	10	20	.50		DOM
139	JOHN STOVER	76			65	49		6				15					DOM
141	MIKE WEEKS	26			225	33		6				30	2			1	DOM

GLOSSARY

Alluvium	A general term for sediments deposited in recent geological time by a stream or other body of water.
Anticline	An upfold of layered rocks in the form of an arch and having the oldest strata in the center. The reverse of a syncline.
Aquiclude	A geologic formation, group of formations or part of formations that does not have enough permeability to supply appreciable quantities of water.
Aquifer	A geologic formation, group of formations or part of formations that is capable of supplying water to wells in usable quantities. An aquifer is unconfined (water table conditions), or confined (artesian conditions) depending on whether the groundwater level is at atmospheric pressure, or greater than atmospheric pressure due to the presence of an overlying confining geologic formation (aquiclude).
Aquifer System	A group of inter-related aquifers.
Artesian Well	A well in which the water rises under artesian pressure above the top of the aquifer the well penetrates, but does not necessarily reach the land surface.
Bedding Plane	The diversion plane in sedimentary or stratified rocks which separates the individual layers, beds or strata.
Bedrock	Any solid rocks exposed at the surface or overlain by unconsolidated materials.
Breccia	General term for a rock of any origin containing angular particles.
Carbonate Rock	A rock consisting chiefly of carbonate minerals, such as limestone, dolomite.
Clastic Rock	A consolidated sedimentary rock composed of broken fragments that are derived from pre-existing rocks, e.g. sandstone, conglomerate, or shale, etc.
Colluvium	Loose soil material and/or rock fragments deposited by the action of gravity, usually at the base of a slope or cliff.

Consolidated	A rock that is firm and rigid in nature due to the natural interlocking and/or cementation of its mineral grain components. The reverse is unconsolidated.
Cross-Section	A diagram or drawing that shows features transected by a given plane; e.g. geologic feature such as geologic structure.
Dip	The angle at which a rockbed is inclined from the horizontal.
Dolomite	A sedimentary rock composed of calcium and magnesium carbonate.
Drawdown	The difference between static level and pumping level in a well, i.e. the drop in the water level due to pumping.
Evapotranspiration	The process by which surface water, soils and plants release water vapor to the air.
Fault	A fracture or fracture zone along which there has been movement of two rock masses relative to one another parallel to the fracture. The movement may be a few inches or many miles, horizontal or vertical.
Fissile	An adjective describing rocks that split along closely spaced parting planes.
Flood Plain	The strip of relatively smooth land adjacent to a river channel and built of alluvium carried by the river during floods. The flood plain is covered by water when the river is in flood.
Fold	A bend in the rock strata.
Formation	A unit of geologic mapping consisting of some one kind of rock.
Fracture	Break in rocks.
Granite	A coarse-grained igneous rock consisting of feldspar, quartz, and other minerals.
Groundwater	Water below the water table, i.e. in the zone of saturation.
Igneous Rocks	Rocks formed by solidification of deep-seated molten silicate materials.
Infiltration	The flow of water through the soil surface into the ground.

Joint	A fracture in rock along which no appreciable movement has occurred. Joints are generally perpendicular to bedding planes.
Karst	A terrain, generally underlain by limestone in which the topography is chiefly formed by the dissolution of rock and which is commonly characterized by closed depressions (sinkholes) and caves.
Limestone	A sedimentary rock consisting predominately of calcium carbonate.
Lithology	The composition and structure of rock. Adjective: Lithologic
Metamorphic Rocks	Rocks formed within the earth crust by the transformation of a pre-existing rock in the solid state without fusion and without addition of new material, as a result of high temperatures, high pressures, or both.
Permeability	The capacity of a rock or soil for transmitting water.
Porosity	The spaces or voids in rock and soil materials usually expressed as a percentage of the material.
Potentiometric Surface	The level to which groundwater rises in a well or an aquifer (in a water table or unconfined aquifer, it is the water table; in an artesian or confined aquifer, it is the piezometric surface, also called artesian head: water level above the top of the penetrated aquifer).
Quartzite	A very hard but unmetamorphosed sandstone.
Recharge	The addition of water to an aquifer by natural infiltration or artificial means.
Runoff	That part of precipitation that appears in surface streams.
Sandstone	Sedimentary rock consisting predominately of sand-size particles.
Schist	A well-foliated metamorphic rock in which the component flaky materials (mica) are distinctly visible.
Sedimentary Rocks	Refers to rocks formed from the consolidation of layered sediments that have accumulated in water.

Sinkhole	A funnel-shaped depression in the land surface, usually in a limestone region, developed by dissolving action of water and usually connected with underlying solution channels or cavities.
Slate	A metamorphic rock formed by the metamorphism of shale.
Structure	The general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area, also referred to as "structural geology".
Subsidence	A local mass movement that involves principally the gradual downward settling or sinking of the earth's surface.
Syncline	A downfold with troughlike forms and having youngest rock in the center.
Terrace Deposits	Deposits of alluvium (sand, gravel, cobble or clay) which occurs along the margin and above the level of a body of water, marking a former water level.
Topography	The relief and form of a land surface.
Water Table	The upper surface of the zone of saturation. The surface in water table aquifer at which the water level stands.
Water Well	An artificial excavation (pit, hole, tunnel) generally cylindrical in form and often walled in, sunk (drilled, dug, driven, bored, jetted) into the ground to such a depth as to penetrate water-yielding rock and to allow water to flow or to be pumped to the surface.

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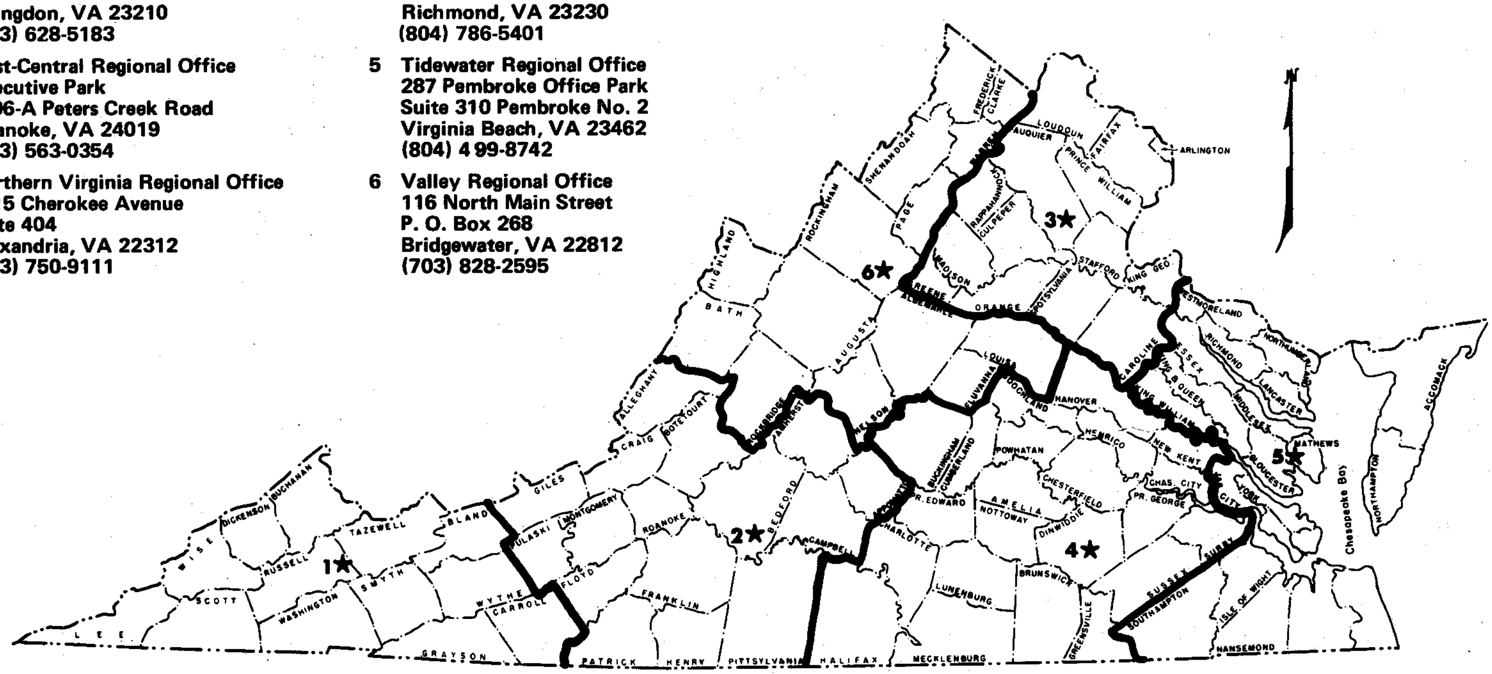

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